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INFORMATION SYSTEMS EDUCATION JOURNAL

Editors

Connecting the Dots and Nodes:
A Survey of Skills Requested by Employers for Network Administrators

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Abstract

One definition of a network administrator describes a person who works with computer infrastructures with an emphasis on networking. To determine the specific skills required of a network administrator by employers, data was collected from 698 nationwide job advertisements on Dice.com. The data collection focused on technical skills rather than soft skills. The requested skills were then broken into various categories in the networking and computing world such as routing protocols, operating systems, virtualization technologies, etc. Educational requirements in terms of degrees and certificates were also tabulated. The results show a great breadth in the requested skills and the summary results will be helpful for curriculum development/review, for career advising, and to faculty teaching in the Information Systems field.

Keywords: network administrator, skills, networking, job description, education.

1. INTRODUCTION

The Role of Computer Networking
Technology continues to increasingly become an integral part of our lives. Networking is an important, critical aspect of technology. We use it for almost everything: work, education, entertainment, shopping, keeping in touch with loved ones, meeting new people. A computer network allows nodes to share resources. They allow for sharing of files, sharing of printers, communications such as email and chat, remote access, and data protection.

There are numerous applications in different fields of business. In marketing they are used to collect, exchange, and analyze data to target customers. In sales, teleshopping allows customers to quickly search for products, read reviews, compare prices and process an order. Computer networks are now used extensively in manufacturing, including computer assisted manufacturing (CAM) and computer assisted design (CAD), allowing several employees to work on projects simultaneously.   Financial services are almost completely dependent on networks - allowing transfer of funds instantaneously, foreign exchanges, stock

purchase and sales, and many other applications. Teleconferences and videoconferencing allow easy communication in meetings with worldwide participants. The entertainment industries can now provide video on demand of almost unlimited content. Other common applications include information services, electronic messaging, electronic data interchange, directory services, and cellular telephone (Tiwari, 2016).

The Role of a Network Administrator
According to Wikipedia, "A **network administrator** maintains computer infrastructures with emphasis on networking. Responsibilities may vary between organizations, but on-site servers, software-network interactions as well as network integrity/resilience are the key areas of focus" (en.wikipedia.org, 2012).

Several key duties of a network administrator include: working with users to establish network specifications, evaluating network performance issues, maintaining network performance, securing the network, preparing and supporting users, continuously upgrading the network, meeting financial requirements/budgeting, continually updating job knowledge, protecting the organization's confidential information, and aiding in accomplishing the organization goals (Hiring.monster.com, 2004).

Job Demand and Wages
The 2015 edition of the U.S. Bureau of Labor Statistics Occupational Handbook predicts that employment for network and computer systems administrators will grow 8% between 2014 and 2024, which is about the average growth for all occupations. This will increase the number of jobs in 2014 (382,600) by 30,200 to 412,800 in 2024. They report a median annual wage as of May 2016 to be $79,700. This was slightly lower than the median of all computer occupations ($82,860), but much higher than the median of all occupations ($37,040). The lowest 10% in the field earned less than $48,870 and the highest 10% earned more than $127,610.

The largest employers were computer systems design (16%), information (11%), state, local, and private educational services (10%), finance and insurance (8%), and administrative and support services (7%). Of these categories, employees working in Information earned the highest (median $85,960), and not surprisingly employees in education services earned the least (median $68,510) (US DoL, 2015).

Roberthalf.com paints a rosier salary picture, and projects a starting salary in 2017 for network administrators ranging from $78,000 to $117,750 - a 4% increase over 2016. Salaries vary widely by location (Badion, 2016).

Salary.com breaks Network Administrator salaries into 5 main categories, Network Administrator I (median $57,601), Network Administrator II (median $75,108), Network Administrator III (median $87,324), Network Administrator IV (median $103,979), and Network Administrator V (median $122,919). This site also allows prospective employees to check median salaries based on job title, education, years experience, location, and other factors (Salary.com, 2017).

2. EDUCATION

A search of over 7500 college/universities on mymajors.com for programs titled "Network and System Administration/Administrator" found a total of 246 program offerings. Eighty of these were 4-year programs, 151 were 2-year programs, and 15 were less than 2-year programs. One hundred and thirty-three of the 246 were offered through public institutions, 11 were private not-for-profit institutions, and 102 were private for-profit institutions. A majority (186 out of 246) of them were offered as online programs. Closely related program searches revealed 874 institutions with "Computer Systems and Networking" programs and 292 institutions with "System, Networking, and LAN/WAN Management" programs. Of course there are many additional institutions that may offer a concentration, emphasis, or certificate under a more general Information Systems, Computer Science, Information Technology, or Engineering degree program (mymajors.com, 2017).

Professional organizations have offered recommendations of how much networking and telecommunications topics should be included in general bachelor computer degree programs. The "Information Technology 2008 Curriculum guidelines for Undergraduate Degree Programs in Information Technology" recommends 22 core hours in networking in an Information Technology degree. An additional 59 hours are recommended in closely related areas (platform technologies, information assurance and security, and web systems and technologies. This joint work by the Association of Computing Machinery (ACM) and Institute of Electrical and Electronics Engineers (IEEE) has not been updated since 2008 (ACM, 2008). Updated guidelines are expected to be

completed in 2017. The "IS 2010 Curriculum Guidelines for Undergraduate Degree Programs in Information Systems" do not specify any recommended number of hours in networking and telecommunications but instead just list Enterprise Architecture and IT Infrastructure as two of the seven recommended areas of study (ACM, 2010). The Accreditation Board for Engineering and Technology (ABET) also does not indicate the number of hours in different areas, just that students are required to be exposed to networking topics (ABET, 2010).

3. WHAT EMPLOYERS WANT

Job ads for computer specialists vary greatly in listed skill requirements. Kasson notes "Many employers required skill sets seem to include everything but the ability to teleport and build a Shaker barn; the lengthy requisites of skills and experience seem achievable only by candidates who've spent the past four decades using a hundred different programming languages and platforms to excel at fifty different, complicated jobs." Other job ads may just list the job title and a few very general skills such as problem solving. Sometimes an employer is unsure what it wants/needs in a new hire, and will add additional responsibilities to be "safe". At some companies, HR managers write the job descriptions and they are written very generic and vague and may not represent at all what is really needed (Kasson, 2015).

A review of the literature reveals several efforts to identify employer needs in IS/IT. Janicki developed a survey with the assistance of 20 IT professionals from various areas to analyze employer needs. Employers were asked to rate desired knowledge in different topics from 1 (not needed) to 4 (expert level needed). From 308 responses to the survey they summarized results by curriculum topic. They conclude that "regardless of the occupation, the employers expected a working knowledge of system documentation, security, IT ethics and privacy, problem identification, specific programming language and process analysis (Janicki, Lenox, Logan, & Woratschek, 2008). Nelson presents a methodology for using Latent Semantic Clustering to analyze a comparison of job skills requirements between small and large firms (Nelson, Ahmad, Martin, & Litecky, 2007). Morris identifies and categorizes skills requested for Network Engineers (Morris, Fustos, & Haga, 2012).

Shankararaman and Gottipati present a solution model for generating a skills report based on the Skills Framework for the Information Age (SFIA) (Shankararaman & Gottipati, 2016). The skill generator takes in curriculum and LinkedIn profile data as input, and generates a list of recommended jobs that match the student's skills. Legier presents an analysis of job characteristics of information systems graduates based on 72 graduates of an information systems program at a midwestern university (Legier, Woodward, & Martin, 2013). Litecky uses a web mining application to extract nearly a quarter of a million unique IS/IT job ads from Monster.com, HotJobs.com, and SimplyHired.com (Litecky, Aken, Ahmed, & Nelson, 2010). The data was then analyzed using cluster analysis. Mirza uses Holland codes to try to identify suitable job roles for IT job seekers by analyzing their personality (Mirza, Mulla, Parekh, Sawant, & Singh, 2015).

A review of the literature revealed no papers specifically addressing the technical skills employers are looking for in a Network Administrator position. This research is intended to fill that gap.

4. METHODOLOGY

A national search for jobs with "Network Administrator" in the title was performed at Dice.com. Dice.com is one of the major job boards for technical positions. A total of 698 sequential job positions were downloaded from September 2014 through October 2016. Obvious duplicate jobs were eliminated. Only positions with the exact title "Network Administrator" were selected. Job requirements for the 698 jobs were examined. The requested skills were categorized by types of protocols, standards, operating systems, etc. and tabulated. This paper addresses just the technical skills employers are asking for. As one would expect, many of the ads also requested generic and "soft skills".

5. RESULTS

The following tables show how the results were categorized. The tables show routing protocols, other protocols, LAN and WAN topics, operating systems and types of servers plus server technologies, security protocols, languages and scripting, education requirements such as degree and certificate requirements, and networking vendors.

Table 1 indicates the number of jobs that listed specific routing protocols or the term "Router". Border Gateway Protocol (BGP) was the most frequently requested protocol appearing in 14.2% of the positions. It is an exterior gateway protocol

(EGP) that is used to link autonomous systems. Both Open Shortest Path First (OSPF) and Enhanced Interior Gateway Routing Protocol (EIGRP) are interior gateway protocols (IGP) and occur in 10.9% and 8.9% respectively of the jobs. The general term "Router" in the job ads just adds emphasis to the importance of this area in general. Cisco's Internetwork Operating System (IOS) is used to configure Cisco switches and routers and was requested by 9.6% of companies. The Juniper switch and router configuration language, Junos OS, also appears in Table 1. Three entries in the table are First Hop Routing Redundancy (FHRP) protocols: Hot Standby Router Protocol (HSRP), Virtual Router Redundancy Protocol (VRRP), and Gateway Load Balancing Protocol (GLBP).

Routing Protocols/Concepts	n	%
Router	365	52.3%
Border Gateway Protocol (BGP)	99	14.2%
Open Shortest Path First (OSPF)	76	10.9%
Cisco Internetwork Operating System (IOS)	67	9.6%
Enhanced Interior Gateway Routing Protocol (EIGRP)	62	8.9%
Hot Standby Router Protocol (HSRP)	26	3.7%
Virtual Router Redundancy Protocol (VRRP)	12	1.7%
Junos OS	11	1.6%
Gateway Load Balancing Protocol (GLBP)	5	0.7%

Table 1. Routing-related Protocols/Concepts

Table 2 lists the other protocols requested. As one would expect, Internet Protocol (IP) had the largest percentage of requests (32.2%), due to the vast body of knowledge it covers such as subnetting, and understanding addressing in terms of route aggregation. IPv4 and IPv6, the specific versions of IP, showed up in only 2.6% and 1.7% respectively of the jobs. Domain Name System (DNS) is the second most requested knowledge area as expected as it is an integral part of networking. In terms of transport-layer protocols, Transmission Control Protocol (TCP) was requested in 22.8% of the ads but User Datagram Protocol (UDP) only showed up in 1.1% of ads. Voice over IP (VoIP) is the fifth most requested item (22.1%) indicating the increasing role of VoIP systems in business.

Other Protocols	n	%
Internet Protocol (IP)	225	32.2%
Domain Name System (DNS)	191	27.4%
Hypertext Transfer Protocol (HTTP)	184	26.4%
Transmission Control Protocol (TCP)	159	22.8%
Voice over Internet Protocol (VoIP)	154	22.1%
Dynamic Host Configuration Protocol (DHCP)	138	19.8%
Simple Mail Transfer Protocol (SMTP)	37	5.3%
Simple Network Management Protocol (SNMP)	93	6.2%
File Transfer Protocol (FTP)	26	3.7%
Windows Internet Name Service (WINS)	21	3.0%
Network Address Translation (NAT)	19	2.7%
Secure Hypertext Transfer Protocol (HTTPs)	19	2.7%
IPv4	18	2.6%
IPv6	12	1.7%
User Datagram Protocol (UDP)	8	1.1%
Internet Message Access Protocol (IMAP)	8	1.1%
Secure File Transfer Protocol (sFTP)	7	1.0%

Table 2. Other Protocols

The most requested application-oriented protocol is HTTP (26.4%). In addition to DNS, DHCP was also a frequently requested networking protocol.

WAN Services	n	%
WAN	273	39.1%
Multiprotocol Label Switching (MPLS)	68	9.7%
T1	18	2.6%
Frame Relay	11	1.6%
T3/DS-3	8	1.1%
Digital Subscriber Line (DSL)	8	1.1%
Synchronous Optical Networking (SONET)	6	0.9%

Table 3. WAN Services

Table 3 shows the most-requested Wide Area Network (WAN) services. General wide area network experience was requested in 39.1% of the positions. Multiprotocol Label Switching

(MPLS) was the most requested. It was a surprise to see T1s requested at all given their low bandwidth and also unexpected to see it requested more than T3s.

LAN topics are tabulated in Table 4. Knowledge of Virtual Local Area Networks (VLAN) was the most requested topic (8.2%) in this section with Spanning Tree Protocol - 802.1d the next most requested (3%).

LAN Topics	n	%
Virtual Local Area Network (VLAN)	57	8.2%
Wireless LAN (WLAN)	45	6.4%
Spanning Tree Protocol - 802.1d	21	3.0%
Aruba Wireless	10	1.4%
VLAN Trunking Protocol (VTP)	9	1.3%
Network Time Protocol (NTP)	7	1.0%

Table 4. LAN Topics

Operating Systems and Related Areas	n	%
Active Directory	226	32.4%
Windows Server 2000/2003/2008/2012	166	23.8%
Linux	134	19.2%
Windows 7	58	8.3%
Group Policy	57	8.2%
Unix	50	7.2%
Windows XP	31	4.4%
Red Hat	27	3.9%
LDAP	16	2.3%
CentOS	12	1.7%
Mac OS X	12	1.7%
Android	12	1.7%
Domain Controllers	12	1.7%
Windows 10	5	0.7%
Debian	5	0.7%

Table 5. Operating Systems and Related Areas

Operating systems and related concepts are tabulated in Table 5. Some version of Windows Server was requested in 23.8% of positions. Areas related to Windows Server such as Active Directory (32.4%), Group Policy (8.2%) and Lightweight Directory Access Protocol (2.3%),

and Domain Controllers (1.7%) are also featured in the table.

Linux along with its variations Red Hat, CentOS, and Debian also scores high. Of the Windows client operating systems the most requested was Windows 7 at 8.3%.

In terms of Database Managements Systems (DBMS) knowledge required, the term Structured Query Language (SQL) appeared in 14.9% of positions – see Table 6. The two most requested DBMSs are Microsoft SQL Server (8.3%) and Oracle (2.7%). The higher percentage for SQL Server could correlate with the large number of positions using a version of Windows Server for their network operating system.

Database-related Solutions	n	%
SQL	104	14.9%
Microsoft SQL Server	58	8.3%
Oracle	19	2.7%
MySQL	12	1.7%

Table 6. Database-related Solutions

The requested web servers are tabulated in Table 7. Microsoft IIS Server (6.4%) is the most requested. The other requested system is Apache, which runs on Linux machines.

Web Servers	n	%
Microsoft IIS Server	45	6.4%
Web Server	20	2.9%
Apache	10	1.4%

Table 7. Web Servers

Other Servers	n	%
Microsoft Exchange	200	28.7%
SharePoint	51	7.3%
File Server	28	4.0%
Print Server	8	1.1%
Application	4	0.6%

Table 8. Other Servers

In addition to the aforementioned database and web servers, other servers such as email, file and print servers also appeared in the ads. The most requested of these by far is Microsoft Exchange Server (28.7%) – see Table 8.

Table 9 shows the popularity of virtualization, a technology that is often associated with cloud computing. The most requested virtualization software is VMWare in 31.5% of the jobs with Microsoft's Hyper-V a distant second (7.7%).

Server, Storage, and Virtualization Technologies	n	%
VMware	220	31.5%
Storage Area Network (SAN)	136	19.5%
Virtualization	97	13.9%
Hyper-V	54	7.7%
VMWare Vsphere	36	5.2%
ESX	35	5.0%
Network Attached Storage (NAS)	32	4.6%
High Availability	27	3.9%
RAID	7	1.0%
Blade/Blade Servers	6	0.9%

Table 9. Server, Storage, and Virtualization Technologies

Security Protocols/Technologies	n	%
Virtual Private Networks (VPN)	228	32.7%
Firewall	169	24.2%
Anti-virus	77	11.0%
Secure Socket Layer (SSL)	44	6.3%
Internet Protocol Security (IPsec)	43	6.2%
SonicWall	31	4.4%
Intrusion Detection System (IDS)	22	3.2%
Dynamic Multipoint Virtual Private Network (DMVPN)	12	1.7%
Demilitarized Zone (DMZ)	9	1.3%

Table 10. Security Protocols/Technologies

The importance of security protocols and technologies for the network administrator position is illustrated in Table 10. General concepts like Virtual Private Networks (VPN) and firewalls score high. The protocols Secure Socket Layer (SSL) and Internet Protocol Security (IPsec) were also requested in a reasonable number of jobs, at 6.3% and 6.2% respectively.

Scripting in general is requested in 10% of ads (Table 11) while C (5.2%) and Microsoft's

scripting platform, PowerShell (3.4%), were the two most requested tools.

Languages/Scripting	n	%
Scripting	70	10.0%
C	36	5.2%
PowerShell	24	3.4%
Perl	18	2.6%
PHP	11	1.6%
Python	10	1.4%
C#	4	0.6%

Table 11. Languages/Scripting

The next two tables show degree and certificate requirements for the 698 jobs surveyed. Table 12 shows the degrees requested. A Bachelors degree was the most commonly requested with zero requests for a Masters degree. A small percentage required only a High School diploma. Degrees in Computer Science and Information Systems were the two most common computer-related degrees for a network administrator position. One could argue that an Engineering degree is the one that is least related to the job title but it scored second in terms of specific degree requests.

Degree Requirements	n	%
Bachelors Degree	287	41.1%
Degree in Computer Science	199	28.5%
Degree in Engineering	119	17.0%
Degree in Information Systems	94	13.5%
High School Diploma	16	2.3%

Table 12. Degree Requirements

The numerous certificates required in the positions are shown in Table 13 and broken down by company/organization/area: Cisco, Microsoft, CompTIA, Security, and Juniper. As expected, the Cisco and Microsoft certificates were the most requested. Cisco Certified Network Associate (CCNA) scored the highest with Cisco Certified Network Professional (CCNP) and Microsoft Certified Systems Engineer (MCSE) in second and third positions respectively.

Certificate Requirements	n	%
Cisco		
Cisco Certified Network Associate (CCNA)	196	28.1%
Cisco Certified Network Professional (CCNP)	109	15.6%
Cisco Certified Internetwork Expert (CCIE)	25	3.6%
Cisco Certified Design Professional (CCDP)	9	1.3%
Cisco Certified Entry Networking Technician (CCENT)	7	1.0%
Microsoft		
Microsoft Certified Systems Engineer (MCSE)	72	10.3%
Microsoft Certified Systems Administrator (MCSA)	25	3.6%
Microsoft Certified IT Professional (MCITP)	18	2.6%
CompTIA		
Network +	39	5.6%
A+	34	4.9%
Security		
Security +	35	5.0%
Certified Information Systems Security Professional (CISSP)	11	1.6%
DoD 8570 Compliant	8	1.1%
Information Technology Infrastructure Library (ITIL)	22	3.2%
Juniper		
Juniper Networks Certified Associate (JCNIA)	7	1.0%
Juniper Networks Certified Professional (JNCIP)	4	0.6%

Table 13. Certificate Requirements

The data in Table 13 is important information, as are the protocols and technologies in the other tables, to share with students.

The last table indicates which vendors appeared in the job requirements. Juniper makes a good showing after the expected numbers 1 and 2, Cisco and Microsoft respectively. It is important to note a vendor's name could show up in an ad in relation to a switch/router, a certificate, or a product. An example of the latter would be Palo Alto, which could occur due to its firewall technology.

Vendors	n	%
Cisco	427	61.2%
Microsoft	277	39.7%
Juniper	70	10.0%
Citrix	60	8.6%
HP	55	7.9%
Dell	54	7.7%
Apple	46	6.6%
SolarWinds	43	6.2%
Palo Alto	37	5.3%
Avaya	25	3.6%
Aruba	20	2.9%
IBM	15	2.1%
Barracuda	14	2.0%
Nortel	12	1.7%
Alcatel-Lucent	3	0.4%

Table 14. Vendors

6. CONCLUSIONS

The results contain a vast store of information for faculty teaching in the networking area and also for curriculum development. The first 13 tables show the breadth of knowledge that could be expected from a person applying for a network administrator position, skills in such diverse areas as routing protocols and switch/router configuration languages (Table 1), operating systems (Table 5), server/storage/virtualization technologies (Tables 6 – 9) and security protocols and technologies (Table 10). The results also give an idea of some of the most important skills and concepts in terms of the requested numbers with IP (32.2%), DNS (27.4%), Active Directory (32.4%), VMWare (31.5%), and VPNs (32.7%) scoring high in the requested skills among the 698 ads.

The tables can be used as a basis to review/develop the networking part of the computing curriculum. Faculty could look at the top two entries or so in each table or at entries that were requested in more than 20% of the job ads and see if these items are covered in the courses. How detailed should the coverage be? An introductory level seems reasonable as students will have to continue learning for life on the job and preparing for certifications. Looking at Table 1 – Routing Protocols/Concepts as an example we see that BGP and OSPF should be covered. The third item in that table is the Cisco IOS. So the

concepts of OSPF should be covered and a simple configuration scenario for OSPF could be demonstrated using some IOS simulator package. Another example is Table 3 – WAN Services. Textbooks typically cover T1/T3s, Frame Relay, and SONET, but this table shows it is worthwhile to add some coverage of MPLS.

The level of expertise expected was not addressed directly in the job ads but they did indicate years of experience needed. 115 positions requested a minimum of three or more years of experience. Coupled with the 28.1% of job ads that expected Cisco's CCNA certificate, and the 15.6% that expected Cisco's top CCNP certificate, this indicates that these are not entry level positions in general.

The results also allow faculty to advise students in terms of education and certificate requirements. Degree-seeking students will be happy to learn that 41% of the positions requested a Bachelors degree. On the other hand, the demand for certificates shows how demanding the workplace can be with 28.1% of the positions requesting Cisco's CCNA certificate. This certificate was found to be so challenging that Cisco split it into two exams. Requiring this CCNA certificate in the ads shows the technical level of expertise expected in the routing and switching areas. Further evidence of this is the 15.6% of ads requesting the CCNP, the advanced Cisco networking certificate.

In summary these results can help faculty in teaching, career advising, and curriculum review and development.

7. FUTURE RESEARCH

As noted previously, this paper addresses just the technical skills requested by employers. It may be interesting to try to also measure the frequency/importance of various generic/soft skills requested.

From the ads, we were unable to directly discern the level of mastery of the various skills employers were looking for. This would likely require doing a survey of employers and asking them to rate the requested skill level from 1 to 5, where 1 would be a superficial knowledge and 5 would be complete expertise.

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Editor's Note: