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A Review of Virtualisation and Cloud Computing for Higher Education



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INTRODUCTION

Virtualisation in the classroom provides students with the impression that they are interacting with applications, services, and files which are stored locally, when in fact the applications, services, and files may be stored on a server off site, or at an alternative location on site. "Virtualization is a technology that permits the abstraction of the software from one computer and its easy deployment in another one, which may house additional virtualized machines" (Martín, Marrero, Urbano, Barra, & Moreira, 2011, p. 349). Server virtualisation is when an Information Technology manager or computer administrator partitions a server to create several instances of virtual servers, thereby multiplying the working capacity of the physical server.

"Network virtualization serves as an effective method for providing a flexible and highly adaptable shared substrate network to satisfy the diversity of demands" (Gang, Hongfang, Lemin, Anand, & Hao, 2011, p. 381). The objective in using network virtualisation is to save on the cost of power and resources by centralising administration and improving the utilisation of hardware and software resources. Therefore, enabling students to consume applications and services as required, while unaware of the fact that the operating system and applications which they are using are stored, operated, and running remotely. Students can access a standardised desktop interface from any thin client on campus to access their work, eliminating the need to work from a specific laboratory or desktop.

This article reviews how cloud computing can be achieved in higher education by leveraging the use of technologies such as virtual machines and thin clients. The background section provides a brief overview of how virtualisation and cloud computing are achieved.

The next section provides a discussion of some of the advantages and disadvantages of virtualisation. Issues, controversies and problems associated with the implementation of virtualised systems are then reviewed. Followed by: solutions and recommendations; future research directions; conclusion; references and additional readings.

BACKGROUND

The background section provides the reader with some information on the following: virtualisation and cloud computing; and the use of virtualisation for higher education, to assist the readers understanding of how virtualisation can be realised.

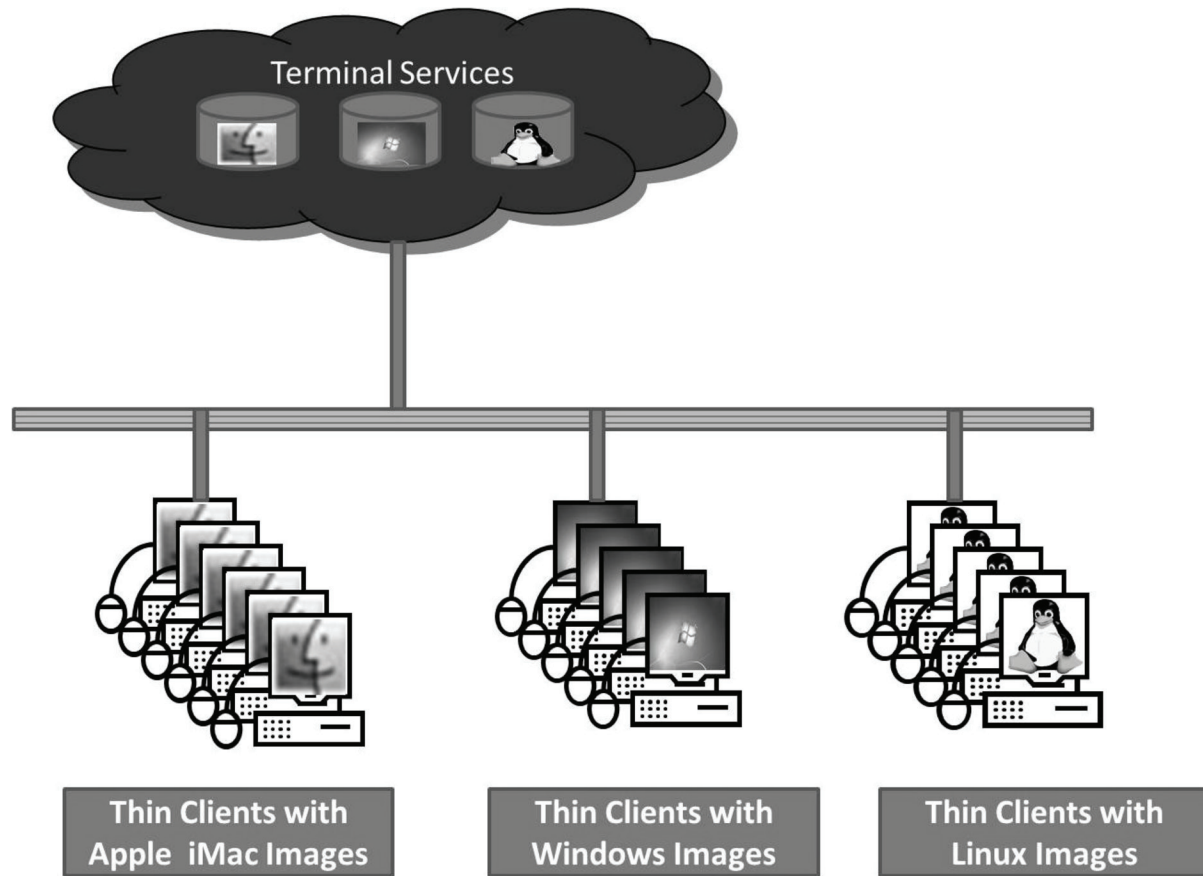
Virtualisation and Cloud Computing

This section explains how Terminal Services and Thin Clients are used to realise virtualisation.

Figure 1. shows how Terminal services can provide the same operating system to many work stations in the same laboratory. Alternatively, terminal services can provide each individual user with the operating system they specifically require, be it an Apple, Windows or Linux environment. Terminal Services are hosted by a terminal server to provide multiple client sessions simultaneously in an attempt to reduce the cost of providing information technology services. Terminal Services (TS) refers to software installed on a server which provides a view into the image which will be displayed on the thin clients for student use. "Server applications are required to operate continuously and remain highly responsive to frequent client requests" (Liu, Wang, Li, & Gaudiot, 2011, p. 452).

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Figure 1. Virtualisation: Terminal services



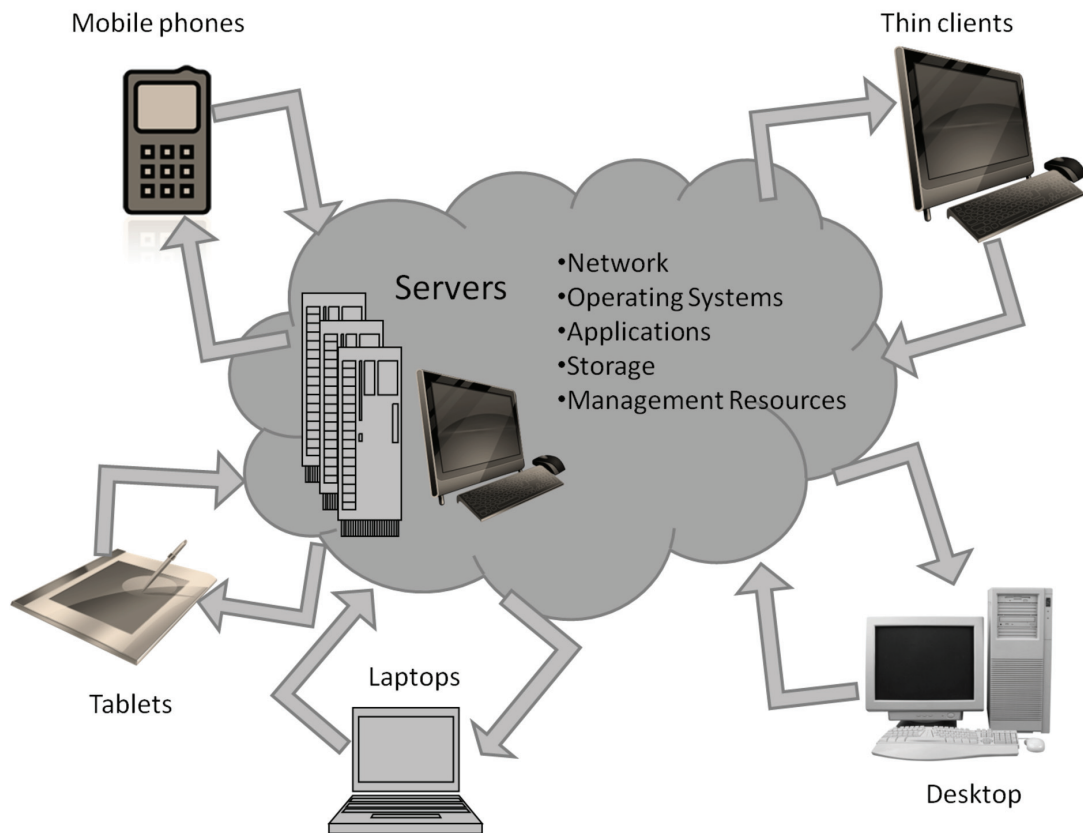
A thin client does not contain the same central processing unit, hard drive, random access memory and data stores as a desktop personal computer, instead thin clients rely on host servers to provide the computing resources users require via the web. Due to reduced functionality thin clients are cheaper to purchase than desktops. The use of thin clients for student use enables the partitioning of servers to create virtual machines which appear to the user as powerful computer devices. “The central server in a thin client network is often called the ‘terminal server’. It is a powerful, high specification machine, capable of handling a large number of logged-in clients” (NCTE, 2008, p. 19).

Figure 2. shows how operating systems, applications and storage spaces contained on centrally stored servers can be accessed by mobile phones, thin clients, desktops, laptops and tablets. Cloud computing implies the delivery of computing services over a network (Internet or Intranet), to provide Information Technology as a service (ITaaS).

Virtualisation for Higher Education

Increasingly educational providers are expanding the use of technology to enhance the profile and quality of the courses on offer through the use of electronic course profiles (ECPs) (Wadley, 2010). Recent negative changes in the finances of world economies are having an adverse effect on the budgets available to higher education (Powell, Gilleland, & Pearson, 2012). Therefore, managers in higher education are endeavouring to maintain IT services at reduced cost. The achievement of virtualised computing through the use of thin clients is one approach which may prove attainable in achieving this aim. “Higher education certainly serves both the market and democracy” (Suspitsyna, 2012, p. 67) and society in general, hence, there is a requirement to at least maintain the quality of services provided and if at all possible continuously improve the IT services offered.

Figure 2. Cloud Computing



Solid evidence of the impact which information and communications technology (ICT) has on the learning experience of students is still lacking despite the fact that computers have been used in education for over twenty years (Rodríguez, Nussbaum, López, & Sepúlveda, 2010). The impact which ICT has on the learning experience of students has yet to be proven, but, the accessibility to knowledge, lecturers and peers enabled by ICT cannot be denied. No longer do students have to queue in libraries to reserve books or access journals, or wait outside classrooms to speak to lecturers; they can now do all this online.

“Technology can play a pivotal role in student learning” (Renes & Strange, 2011, p. 203). “The trend to adopt more online technologies continues unabated in the higher education sector” (Dawson, 2010, p. 736). The use of thin clients may be a cheaper option than desk top personal computers in providing the necessary computing infrastructure to support IT services in the long term.

ADVANTAGES AND DISADVANTAGES OF VIRTUALISATION

Some of advantages and disadvantages of virtualisation are discussed in this section.

Advantages of Virtualisation

Some of the advantages which may be realised by employing the concept of virtualisation of computing resources in the provision of Information Technology in higher education, to reduce the operational costs are discussed in this section. Virtualisation enables savings on hardware, electricity and maintenance costs due to centralisation of services (Martín et al., 2011). By centrally managing resources, the reduction in time Information Technology (IT) staff require to provide and manage the desktop experience leads to a lowering of operational costs (HP, 2010).

Instead of installing applications software which is expensive to license in specific computer laboratories, this software may be stored centrally and accessed as required. If expensive software is stored exclusively in one computer laboratory these expensive applications will not be available for use by students when classes are scheduled for that laboratory. Virtualisation of computer resources will enable students' access to licensed software from any laboratories on campus, facilitating ubiquitous access to expensive applications (Jou & Wang, 2013). To save on cost a limited number of licenses may be purchased and held on the servers, when all the instances of this application are in use simultaneously, students will be advised to try access these applications later. Virtualisation could provide management with an opportunity to balance the educational needs of staff and students with the available computing resources.

Students will have ubiquitous access to their saved files on campus. Thin clients are cheaper than desktops to purchase and maintain, consume less power, and tend to have a longer working life. A longer working life of monitors, keyboards and mice reduces replacement costs, recycling costs, and waste which is harmful to the environment. The Green computing approach is more beneficial to management and the environment by reducing the carbon footprint and greenhouse gases.

One of the main advantages of a Thin Client Network is a "Limited risk of virus attack – as virus management is controlled on servers" (NCTE, 2008, p. 19). Virtualisation affords management the opportunity to streamline practices, for example, by updating the stored image of operating systems and applications on the servers would ensure the same consistent interface would be available for use by each student. The need to ghost each desktop computer with the required image would no longer be necessary if a virtualised system was utilised. Virtualisation can reduce energy through less power consumption and increase security. There are many challenges to be encountered in deploying virtualisation through the use of thin client networks in higher education but "the challenges facing the acceptance of Thin Clients is a combination of architectural design and integration strategy rather than a purely technical issue" (Doyle et al., 2009, p. 585).

The main advantage is centralized management. Installing updates, fixes, patches or changes to installed programmes is minimised to a handful of images which

are then instantly available to all users of the image. Previously this would entail updating hundreds of desktops. Package installers have been used to achieve this, for example, installing Microsoft Installer (MSIs) through Microsoft's Active Directory, or application packages through Novell's Zenworks. For various reasons a portion of the installed base of desktops would either fail to receive the package or fail during the install leaving additional problems to correct.

When a user connects via a thin client to a Terminal Server, the session they use is kept on the Terminal Server, thus any troubleshooting can be done via the server rather needing to visit the client. Even though the thin clients can be old re-used machines, the hardware necessary to run this is minimal and inexpensive. Since no data is stored on the client, these inexpensive clients can be swapped out easily with minimal cost.

The requirements of a thin client system are quite modest compared to the desktops requirements of today. No more than 1GB Ram, 100GB hard disk drive, and a Pentium II or III would suffice. Such a system would barely run Windows 98 (Microsoft, 2013a), but it will run and work well as a thin client in a Terminal Services environment.

User monitoring is also easier managed; user monitoring is done at the server, therefore there is no need to visit the user's workstation. When a server is upgraded a large number of users benefit simultaneously.

Disadvantages of Virtualisation

Maintenance issues and faults with servers and incompatibility issues with software applications can cause problems. Some Terminal servers can handle in excess of fifty attached devices. If a problem occurs with a server, all fifty attached thin clients will lose their sessions at once, which is not ideal, therefore monitoring and maintenance of the system is crucial to success. Similarly, when any other infrastructure devices (switches, routers, etc.) fail all users lose access to operating systems, applications and files.

Load balancing can create issues. For example, if a user is on machine A, and machine A (or network connection to A) goes down, the student may log in and commence a session on machine B. Their session on machine A could still be running, hence, they may wonder why they do not have access from machine B to the word document which they were working on

when machine A went down, this may be caused by the file on the home directory showing up as “open” or “locked.”

Some individual users may tend to take more of the resources than they require or hold onto the resources for longer than is necessary. Individual users can take over substantial portions of the central processing unit (CPU), memory, and disk and/or network bandwidth affecting all the other users of this Terminal Server. In some cases the service available to users may be reduced due to: hogging of resources caused by students having too many applications or resources opened simultaneously; or possibly caused by a misbehaving application, for example, a leaking memory fault. “Memory leaking is one of the most major software bugs which severely threaten the availability and security of systems” (Kang, Chen, & Jiang, 2010, p. 125). The end result is the same; all users of this terminal server will receive reduced services or possibly experience system crashes.

Some programmes are not very compatible with terminal services. Not all programmes work well in terminal services environments, significant testing must be undertaken to ensure that the applications will operate effectively and efficiently in all modes. The network must be reliable and capable of delivering the traffic to all the workstations.

USB devices can add a layer of complexity to the management of thin clients through the necessity of ensuring that no viruses enter the Terminal server. Unlike a desktop, where the anti-virus programme runs on the desktop, in a Terminal Server environment, the antivirus client runs in every session, taking up valuable CPU and memory resources every time a USB device is connected and files are moved back and forth.

Managing Application licensing can be very complicated in a terminal service environment. Effectively all sessions of a specific image have to be monitored and counted so the system is aware how many instances are still available for users. When the license count is exceeded no additional sessions can be created for user access. This can cause problems, especially in education, for example, when a twenty-five seat computer laboratory cannot acquire sufficient sessions to ensure that all the students can use a specific application at the one time, when the lecturer is present.

Terminal Services implementations can fail due to a variety of issues. The number of users requiring use of specific applications exceeds the limited license count

available. Graphic intensive applications and video editing applications do not work well in this environment due to the extensive use of resources required to effectively run these applications. Therefore, it would be necessary to install desktops in all locations where the use of these applications were required. These are all factors which need to be considered because ultimately it may not be worthwhile or cost effective to operate both systems.

ISSUES, CONTROVERSIES, AND PROBLEMS

Some of the issues, controversies and problems encountered when implementing virtualised systems are discussed in this section.

Issues

Performance of virtualised systems will depend on the usage requirements. “Processor and graphic-intensive applications did not work reliably on some Thin Client networks, and could have an impact on other network users” (British Educational Communications and, 2006, p. 59). Each discipline places different demands on Information and Communications Technology (ICT), the proposed use of Thin Clients would have to be tested and assessed with respect to each discipline prior to implementation. Management in Higher Education should be aware with respect to expected performance “in a thin client network if the server is not fully functional, none of the client machines can operate” (NCTE, 2008, p. 19).

The responsiveness of the virtualised system will depend on the infrastructure (hardware and software), broadband capability, technical expertise of the team who managed the implementation, and user requirements. The implementation team must build some fault tolerance into the virtualised system to facilitate a back-up plan in case of server failure. Interoperability, is another major consideration when implementing a virtualised system, “A higher level of planning is required to ensure that all parts of the system work properly together, hardware, software etc” (NCTE, 2008, p. 19). Scalability and flexibility are other considerations for the implementation team, “Additional flexibility comes from HP’s relationships with all of

the leading virtualisation software vendors, including Citrix (Citrix, 2013), Microsoft (Microsoft, 2013b), and VMware (VMware, 2013)” (HP, 2010, p. 3).

One of the major concerns of information technology providers is security (Foley & Fitzgerald, 2011; Vaquero et al., 2011). Another concern with the implementation of cloud computing is privacy (Srivastava & Kumar, 2011; Yoo, 2011). Cost is another concern (Kotsovinos, 2011).

Controversies

Providing a fault tolerant solution to virtualisation is a critical success factor for the implementation and acceptability of a virtualised environment in higher education. Some may argue that the scalability issues involved in providing virtualisation for a whole campus, which may accommodate twenty thousand or more students, are insurmountable. With respect to cost, can the initial expenditure on the servers, hardware and software resources required to support a virtualised environment be justified? The cost savings to be made by employing the use of virtualisation are disputable. Managers who consider implementing a virtualised solution to provide computing resources for students in higher education would require detailed analysis of the costs involved in implementing a virtualised system to compare with existing costs. Projected costs would need to include: initial outlay on servers and thin clients, storage devices, virtualisation hardware and software, license for applications, direct support charges, ongoing maintenance, technical assistance, training and other infrastructure costs. “Web services are nowhere near achieving the full potential that was hoped for” (Sultan, 2010, p. 109).

Problems

The central server in a thin client network must “be located in a secure locked room and only accessible to the network administrator, as all of the client systems depend on it for their computing power” (NCTE, 2008, p. 19). The security maintained on access to the central server(s) or terminal server(s) is paramount to the successful implementation of thin client networks to provide virtualisation in higher education. Educational institutions are also responsible for securely protecting student information (HP, 2010). One aspect of physical

security of hardware resources is to identify an appropriate means of securing the monitor, keyboard and mouse to ensure they are not illegally removed from the computer laboratories. Another problem concerning security and data protection is that hackers may use sophisticated techniques to steal data by encouraging users to download applications containing Trojans and viruses (HP, 2010).

Students use memory keys (Universal Serial Bus (USB)) to store or back up files, the use of these keys could slow down the virtualised system or create a security hazard by introducing viruses to the virtualised system. Memory keys “are often prone to loss or misuse” (Sultan, 2010, p. 113). To prevent viruses on the USB keys invading the servers, the content of each USB key should be scanned by antivirus software and given the all clear prior to use. On insertion of the USB key, the contents of the USB key must be scanned for viruses by the terminal server, such actions consumes valuable CPU and memory resources and therefore slows down the service offered to the students. The use of USB keys has a direct impact of the performance of the virtualised system. Every time a key is inserted, an anti-virus scan must be performed, the greater the number of files on the key, the longer the time taken to check for viruses, and hence the more CPU resources required. IT Managers may need to investigate other storage solutions for students which will work well in a virtualised environment. “Thin client solutions offer improved security since data is stored centrally” (HP, 2010, p. 3).

A solution to the problem of security in the use of memory keys is to allocate each student storage space in the cloud by utilising applications such as Dropbox (Dropbox, 2012), Skydrive (Microsoft, 2012), or Google Docs (Google, 2012) this would provide students with ubiquitous access to their files. Alternatively, students may be allocated file storage space on one of the terminal servers to store their files, thus eliminating the need to use USB keys in the thin clients, but these files would not be ubiquitously accessible. Another problem is who is accountable should students download and save copyrighted material “If students download copyrighted material and save it to their desktops, there can be civil and criminal penalties assessed” (HP, 2010, p. 2). In addition, “The issue of reliability with relation to cloud computing will continue to be a problem” (Sultan, 2010, p. 114).

SOLUTIONS AND RECOMMENDATIONS

Given the scalability options available within a virtualised environment, it is likely that such controversies can be overcome with adjustments in the number of processor cores available to the Terminal Server (TS). For a full fault tolerant TS environment, an integrated Storage Area Network (SAN) environment will also be required. “Cloud computing and other related paradigms need to converge so as to produce unified and interoperable platforms for delivering IT services” (Buyya et al., 2009, p. 614). Cloud computing may be a solution to managing storage problems and the provision of ubiquitous access to files when off campus, but security issues with Cloud computing would require further investigation. Vaquero et al. (2011) propose the most appropriate solutions to security measures in cloud computing is through access controls and encryption.

FUTURE RESEARCH DIRECTIONS

The use of virtualisation in higher education purports to reduce the cost of providing computer services. Each higher education provider is different; the resources required vary with respect to discipline, the requirement for processing power will depend on demand, before management decide to implement a virtualised solution detailed analysis of requirements, analysis of initial costs and ongoing expenses will be necessary. The proposed use of Cloud computing is to facilitate the storage of files and enable students’ ubiquitous access to their coursework and assignments. Access to educational resources anytime, anyplace can facilitate mobile, contextualised and ubiquitous learning (Glahn, Specht, & Koper, 2009; Hwang & Tsai, 2011) and instructional theories (Peng, Su, Chou, & Tsai, 2009). Technology enhanced learning is expanding globally due to web technologies (Benchicou, Aichouni, & Nehari, 2010). Cloud computing is the way forward in achieving ubiquitous learning for students in higher education.

CONCLUSION

Managers of Information Services in higher education are continually striving to improve services to students while reducing the costs incurred in providing these services. Virtualisation may be a viable solution to reducing the expense of providing computing services to all students on campus. Cloud computing may be the solution to providing all staff and students ubiquitous access to coursework and assignments. Prior to implementing any new systems, extensive testing is required to insure that the proposed solutions will deliver the necessary computing services to users in a timely, cost effective, and efficient manner.

REFERENCES

- Benchicou, S., Aichouni, M., & Nehari, D. (2010). E-learning in engineering education: a theoretical and empirical study of the Algerian higher education institution. *European Journal of Engineering Education*, 35(3), 325–343. doi:10.1080/03043797.2010.483610
- British Educational Communications and T. A. (2006). Thin client technology in schools. literature and project review. In E. B. E. C. a. T. Agency (Ed.).
- Buyya, R., Yeo, C., Venugopal, S., Broberg, J., & Brandic, I. (2009). Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility. *Future Generation Computer Systems*, 25, 599–616. doi:10.1016/j.future.2008.12.001
- Citrix. (2013). *Citrix*. Retrieved on June 7, 2013, from <http://www.citrix.com/>
- Dawson, S. (2010). ‘Seeing’ the learning community: An exploration of the development of a resource for monitoring online student networking. *British Journal of Educational Technology*, 41(5), 736–752. doi:10.1111/j.1467-8535.2009.00970.x
- Doyle, P., Deegan, M., Markey, D., Tinabo, R., Masamila, B., & Tracey, D. (2009). Case studies in Thin Client acceptance. *UbiCC Journal*, 4(3), 585–598.

- Dropbox. (2012). Retrieved October 9 <https://www.dropbox.com/>
- Foley, S. N., & Fitzgerald, W. M. (2011). Management of security policy configuration using a Semantic Threat Graph approach. *Journal of Computer Security*, 19(3), 567–605. doi: doi:10.3233/JCS-2011-0421
- Gang, S., Hongfang, Y., Lemin, L., Anand, V., & Hao, D. (2011). The Framework and Algorithms for the Survivable Mapping of Virtual Network onto a Substrate Network. *IETE Technical Review*, 28(5), 381–391. doi:10.4103/0256-4602.85968
- Glahn, C., Specht, M., & Koper, R. (2009). Visualisation of interaction footprints for engagement in online communities. *Journal of Educational Technology & Society*, 12(3), 44–57.
- Google. (2012). Google Docs. Retrieved on October 9 <https://accounts.google.com/ServiceLogin?service=writely&passive=1209600&continue=https://docs.google.com/%23&followup=https://docs.google.com/<mpl=homepage>
- HP. (2010). Thin Clients make the grade in Education Retrieved on September 20, 2012, from http://www.hp.com/canada/products/landing/thin_clients/files/c02928168.pdf
- Hwang, G.-J., & Tsai, C.-C. (2011). Research trends in mobile and ubiquitous learning: a review of publications in selected journals from 2001 to 2010. *British Journal of Educational Technology*, 42(4), E65–E70. doi:10.1111/j.1467-8535.2011.01183.x
- Jou, M., & Wang, J. (2013). Observations of achievement and motivation in using cloud computing driven CAD: Comparison of college students with high school and vocational high school backgrounds. *Computers in Human Behavior*, 29(2), 364–369. doi:10.1016/j.chb.2012.08.001
- Kang, H., Chen, H., & Jiang, G. (2010). *PeerWatch: A fault detection and diagnosis tool for virtualized consolidation systems*. Paper presented at the ICAM 2010, Washington, DC, USA.
- Kotsovinos, E. (2011). Virtualization: Blessing or Curse? *Communications of the ACM*, 54(1), 61–65. doi:10.1145/1866739.1866754
- Liu, S., Wang, L., Li, X.-F., & Gaudiot, J.-L. (2011). Space-and-Time Efficient Parallel Garbage Collector for Data-Intensive Applications. *International Journal of Parallel Programming*, 39(4), 451–472. doi:10.1007/s10766-010-0151-4
- Martín, D., Marrero, M., Urbano, J., Barra, E., & Moreira, J. (2011). Virtualization: A solution for efficiency, security and management of intranets. *El Profesional de la Informacion*, 20(3), 348–354. doi: doi:10.3145/epi.2011.may.16
- Microsoft. (2012). SkyDrive. Retrieved on October 9, 2012 <http://windows.microsoft.com/en-US/skydrive/home>
- Microsoft. (2013a). Minimum hardware requirements for a Windows 98 installation. Retrieved on June 7, 2013, 2013, from <http://support.microsoft.com/kb/182751>
- Microsoft. (2013b). Server and Cloud Platform. Retrieved on June 7, 2013, from <http://www.microsoft.com/en-us/server-cloud/datacenter/virtualization.aspx>
- NCTE. (2008). Thin Client Networks. Retrieved from <http://test.ncte.ie/documents/advisesheets/19ThinClientNov08.pdf>
- Peng, H., Su, Y.-J., Chou, C., & Tsai, C.-C. (2009). Ubiquitous knowledge construction: mobile learning re-defined and a conceptual framework. *Innovations in Education and Teaching International*, 46(2), 171–183. doi:10.1080/14703290902843828
- Powell, B. A., Gilleland, D. S., & Pearson, L. C. (2012). Expenditures, Efficiency, and Effectiveness in U.S. Undergraduate Higher Education: A National Benchmark Model. *The Journal of Higher Education*, 83(1), 102–127. doi:10.1353/jhe.2012.0005
- Renes, S., & Strange, A. (2011). Using Technology to Enhance Higher Education. *Innovative Higher Education*, 36(3), 203–213. doi:10.1007/s10755-010-9167-3
- Rodríguez, P., Nussbaum, M., López, X., & Sepúlveda, M. (2010). A Monitoring and Evaluation Scheme for an ICT-Supported Education Program in Schools. *Journal of Educational Technology & Society*, 13(2), 166–179.
- Srivastava, K., & Kumar, A. (2011). A New Approach of CLOUD: Computing Infrastructure on Demand. *Trends in Information Management*, 7(2), 145–153.

Sultan, N. (2010). Cloud computing for education: A new dawn? *International Journal of Information Management*, 30(2), 109–116. doi:10.1016/j.ijin-fomgt.2009.09.004

Suspitsyna, T. (2012). Higher Education for Economic Advancement and Engaged Citizenship: An Analysis of the U.S. Department of Education Discourse. *The Journal of Higher Education*, 83(1), 49–72. doi:10.1353/jhe.2012.0003

Vaquero, L., Rodero-Merino, L., & Morán, D. (2011). Locking the sky: a survey on IaaS cloud security. *Computing*, 91(1), 93–118. doi:10.1007/s00607-010-0140-x

VMware. (2013). *VMware Virtualization for desktop & server, public and private clouds*. Retrieved on June 7, 2013, from <http://www.vmware.com/>

Wadley, D. (2010). Towards a best practice electronic course profile. *Teaching in Higher Education*, 15(1), 29–43. doi:10.1080/13562510903488121

Yoo, C. (2011). Cloud Computing: Architectural and Policy Implications. *Review of Industrial Organization*, 38(4), 405–421. doi:10.1007/s11151-011-9295-7

ADDITIONAL READING

Alsaih, M. A., Latip, R., Abdullah, A., & Subramaniam, S. K. (2013). A taxonomy of load balancing techniques in cloud computing. *International Review on Computers & Software*, 8(1), 64–76.

Buyya, R., & Ranjan, R. (2010). Special section: Federated resource management in grid and cloud computing systems. *Future Generation Computer Systems*, 26, 1189–1191. doi:10.1016/j.future.2010.06.003

Deng, Y., & Pung, B. (2011). Conserving disk energy in virtual machine based environments by amplifying bursts. *Computing*, 91(1), 3–21. doi:10.1007/s00607-010-0083-2

Gital, A. Y. u., & Zambuk, F. U. (2011). Cloud Computing: Solution to ICT in Higher Education in Nigeria. *Advances in Applied Science Research*, 2(6), 364–369.

Grandoni, F., Rothvoß, T., & Sanità, L. (2011). From uncertainty to nonlinearity: Solving Virtual Private Network via Single-Sink Buy-at-Bulk. *Mathematics of Operations Research*, 36(2), 185–204. doi:10.1287/moor.1110.0490

James, J., & Verma, B. (2012). Efficient VM load balancing algorithm for a cloud computing environment. *International Journal on Computer Science & Engineering*, 4(9), 1658–1663.

Li, T.-H. (2011). Workload portfolio optimization for virtualized computer systems based on semiparametric quantile function estimation. *Journal of the Royal Statistical Society. Series C, Applied Statistics*, 60(4), 519–539. doi:10.1111/j.1467-9876.2011.00764.x

Limoncelli, T. (2012). OpenFlow: A radical new idea in networking. *Communications of the ACM*, 55(8), 42–47. doi:10.1145/2240236.2240254

Minter, S. (2013). Saving the world one motor at a time. *Industry Week/IW*, 262(1), 48–48.

Subbiah, S., Selva Muthukumaran, S., & Ramkumar, T. (2013). Enhanced Survey and Proposal to secure the data in Cloud Computing Environment. *International Journal of Engineering Science and Technology*, 5(1), 49–53.

Uddin, M., & Rahman, A. A. (2012). Energy efficiency and low carbon enabler green IT framework for data centers considering green metrics. *Renewable & Sustainable Energy Reviews*, 16(6), 4078–4094. doi:10.1016/j.rser.2012.03.014

Wagner, W. P., & Vik, P. (2010). Using Virtual Servers to Teach the Implementation of Enterprise-level DBMSs: A Teaching Note. *Journal of Information Systems Education*, 21(4), 349–354.

Wang, X., Wang, R., & Liu, X. (2013). An adaptive management approach collaborating heterogeneous resources in cloud service environments. *International Review on Computers & Software*, 8(1), 401–408.

KEY TERMS AND DEFINITIONS

Cloud Computing: The delivery of computing services over a network either Internet or intranet.

Green Computing: The provision of information and communications technology while reducing: the carbon footprint; greenhouse gases; and negative impacts on the environment.

Server Virtualisation: Server virtualisation is when an Information Technology manager or computer administrator partitions a server to create several instances of virtual servers.

Terminal Services (TS): Terminal Services are hosted by a terminal server to provide multiple client sessions simultaneously.

Thin Clients: Do not contain the same central processing unit, hard drive, random access memory and data stores as a desktop personal computer, instead thin clients rely on host servers to provide the computing resources users require via the web.

Virtualisation: Virtualisation in the classroom provides students with the impression that they are interacting with applications, services, and files which are stored locally, when in fact the applications, services, and files may be stored on a server off site, or at an alternative location on site.