The Transformation of Education through State Education Clouds

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Introduction

Cloud computing represents a revolutionary technological paradigm shift that can dramatically improve the quality of education for all students in a given state, from K-12 to higher education. Through the Internet, it can deliver the most advanced software and educational materials, hardware resources and services to students and educators in even the most impoverished or remote school districts in the state, without the need for advanced IT expertise at those locations. At the same time, it does more for significantly less, providing needed relief for currently strained education budgets. From an IT-management perspective, it dramatically reduces resource management costs — including power, cooling and system management personnel — while driving up the utilization of servers and software licenses, which in turn reduces purchasing requirements.

The above are not theoretical claims, but are based on the real experiences of production education clouds currently operating within several states. In 2009, the Virtual Computing Lab (VCL) at North Carolina State University (http://vcl.ncsu.edu) delivered more than 220,000 user sessions to North Carolina students and faculty. [1, 2] The VCL was developed as the education and research cloud computing production system for NC State University, which serves more than 30,000 students. Now the VCL also supports students at other universities within the University of North Carolina (UNC) System, and in many schools within the North Carolina Community College System.[3] There are also several K-12 outreach pilots across the state. Similar education clouds based on VCL can be found in Virginia, Georgia, South Carolina and Maryland, as well as within the Historically Black Colleges and Universities (HBCU) community, as part of the HBCU Cloud initiative led by the Technology Transfer Project (TTP). VCL-based education clouds can also be found in India, China, Japan – and most recently (under construction), in Portugal.

The Virtual Computing Lab: A cloud computing solution designed for education

The VCL represents a true cloud computing solution that has been optimized for the educational and research needs of the academic community. It began in 2002, (with the first general production system launched in 2004) by the NC State College of Engineering, the NC State Office of Information Technology, and the NC State Computer Science department.

What is meant by a cloud computing solution? There are a number of circulating definitions for a cloud, but the National Institute of Standards and Technology (NIST) definition is a generally accepted standard: "Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (such as networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction."[4] More simply, a cloud can be considered to be a collection of hardware, software and other resources that can be accessed over the Internet, and used to assemble a solution on demand (that is, at the time of the request) to provide a set of services back to the requester. For example, a university student taking a college math course could access a cloud from his or her dorm room, to obtain a physical or virtual server (with the necessary storage) and a copy of Maple or MATLAB software running on it to use for homework or a class project. Likewise, an elementary school teacher could access the same cloud to request one virtual machine for each of his or her students running TinkerPlots software, as part of his or her classroom instructional activities.

The VCL-based cloud implemented at NC State (NC VCL) supports a wide range of users, from high-performance computing (HPC) researchers to K-12 students. To support computationally intensive work, a researcher can access the VCL website and request a cluster of machines—with (possibly) a different software suite installed on each machine. Using the same infrastructure, a professor can select 20 or more machines for a class of 20 students. A special image can run on each machine, with all the software needed for that

class. The machines can be delivered, say, every Tuesday and Thursday, in time for a class from 2 to 4 p.m. Likewise, a middle-school teacher can pre-schedule VCL machines each day to run Project Lead the Way software for a science, technology, engineering and math (STEM) course. At class time, the teacher rolls out a cart with inexpensive thin clients for the students to access the course.

Once the requester is finished, the resources can then be disassembled and returned to the general pool, to be reallocated again for the next requester. The resources are used only when they are needed, maximizing the utilization of the hardware and software licenses, while minimizing energy costs and purchasing requirements. And access to those resources with the Internet means that they are available 24x7, from a classroom, from a dorm room or from the home.

The VCL managed by NC State today can be accessed by any user with a valid user account and password (http://vcl.ncsu.edu). Technically, all University of North Carolina system students with Shibboleth credentials (about 250,000 students) have access to it. A student or educator can access the site to request one or more real (bare-metal load) or virtual machines to be delivered immediately or at a later scheduled time. An image represents an operating system, typically Microsoft® Windows® or Linux®, running one or more software applications or middleware that can be selected to run on a chosen machine. The website can be accessed by any machine or device that can run a web browser, providing the requester full use of all the resources requested (computing, storage, software and others), The interface is identical to what users would experience if the machines were under the desk—even allowing users to also install other software on the delivered machines.

When making a request at the NC VCL website, each educational institution can access its own "portlet" with a menu customized to appear as a web page for that specific school. Access control can be linked to a school's LDAP, Shibboleth or other sign-on system. The VCL appropriately manages the individual software license agreements (limiting the number of simultaneous licenses in use by authorized users, if required). Group access to software can be managed policies (for example, with class enrollment lists). Relevant usage statistics are collected, and can be used for metering and charge-back, future capacity planning and so on.

NC State has made the VCL freely available as open source, donating the code to the Apache Foundation, and thereby establishing an open source software community development project in which university faculty, students and others can participate (http://incubator.apache.org/projects/vcl.html).

Implementation at NC State with useful economic models

The education cloud managed by NC State consists today of over 2,000 actual physical servers (hosting up to 4,000 to 5,000 virtual servers) and over 800 software images. It is accessible to a quarter million students across North Carolina, from K-12 to higher education. The ways in which it grew to ultimately support such a large number of students is worth a closer look. It highlights the broad applicability of VCL in sup- port of the full spectrum of educational needs using a single architecture. Its range includes the ability to provide complex server clusters to the HPC research community on campus, while at the same time providing virtual desktops with needed software to K-20 students.

VCL development was begun in 2002 in part to address the information technology access needed by NC State students, and in part to compensate for the loss of the North Carolina Supercomputing Center, which had supported its HPC research community. It was designed from the start to simultaneously address the individual, general classroom lab and other educational services needs of the campus. The

result was one of the first true cloud computing infrastructures for university research and education, years before the term cloud computing became popular.

The NC VCL cloud servers are typically divided into two large pools–one supporting the HPC research community needs (http://hpc.ncsu.edu), and one supporting the educational, research and other needs of the general university population (http://vcl.ncsu.edu). Services in each pool have slightly different networking and physical configurations, along with different user policies, available applications and services. However, with VCL allows a system administrator to move resources from one pool quickly to the other. This provides flexibility, maximizes the effective usage of resources, and yields significantly increased economy of operation.

For example, about half of the resources are generally found in the HPC pool, but at the start of classes each semester, servers are transferred from the HPC pool to the general purpose pool (with the trend reversed during summer and vacation times). The HPC pool provides researchers with servers and storage needed for large scale computations. It also provides standard HPC (asynchronous) batch processing, with most standard HPC applications, job queuing, and more.

The servers in the general purpose pool (VCL 24x7) provide typical desktop or server application environments, for in-classroom use, homework, class projects, that are typically reserved for just hours at a time. However, the VCL 24x7 can also provide long-term reservations for servers, and can provision research clouds; for example, a Hadoop subcloud. Professors, teaching assistants or other students with permission have the authority to create and store their own special-purpose images. For example, a professor can select a licensed, base Windows image running on a VCL server (http://vcl.ncsu.edu), install any software needed for a class, and then place that image back in the campus image repository. Students in that class can then simultaneously access multiple copies of the image.

The NC VCL grew quite rapidly as a result of the policies put in place by the NC State Office of IT (OIT) and various campus departments and colleges. NC State HPC researchers in engineering, life sciences and other departments regularly received grants—from the National Science Foundation (NSF), the Department of Defense (DoD) , the National Institutes of Health (NIH) and others— that included funding for servers. However, the funding did not usually cover space, power, cooling, personnel support—all the typically predominant costs associated with operating a server over its lifetime. These costs had to be picked up by the departments or colleges. Hence, these groups enthusiastically supported the "deal" offered by OIT: free operational support for three years, with guaranteed delivery of the sole-use of their server resources whenever they were requested by the funded researchers. In return, OIT defined the server specifications, thereby achieving a homogeneous pool providing the best total cost of ownership (TCO). Additionally, they could "loan" the cycles on those research machines back to the general campus population when they were not being used, which, in fact, could be 50 percent or more of the time..

By judiciously combining HPC batch jobs and VCL 24x7 users, NC State has been able to operate the VCL research and education cloud at a cost of three to twenty cents per compute hour. This matches current subsidized rates provided by some public cloud vendors, without the corresponding reduction in guaranteed quality of service. As the owner of the cloud resources, NC State has better control over the satisfaction of user service level agreements (SLAs) or expectations. During the regular school semester, for its population of over 30,000 users, NC State consistently sees a daily peak plateau of nearly 500 simultaneous, general purpose (non-HPC) users, between 10 a.m. and 10 p.m. This requires a minimum of 500 real or virtual servers allocated each day to support the VCL 24x7 users. This requirement varies by school, depending upon the size and usage patterns. Without the flexibility provided by a VCL-based cloud, most of those real servers would be idle between 10 p.m. and 10 a.m. However, with VCL, during idle times, these resources can be either turned over to batch jobs, or powered down to save energy. By using this approach, especially during vacation breaks, NC State is able to maximize resource utilizations, driving down average cost per CPU.

An important lesson here is that the flexibly dynamic nature of such a cloud infrastructure allows for the utilization peaks and valleys of different jobs and user populations to be judiciously combined to minimize operating costs. The opportunity to perform such highs-lows matching increases as the cloud user population grows. A state-wide education cloud could be created, for example, that combines research, university, community college, K-12 (and even government) users and workloads.

VCL deployment in support of statewide education

VCL support at NC State was rolled out incrementally over several years, starting with select classes and departments in the College of Engineering. It was gradually extended to the other colleges—ultimately providing VCL access to all faculty and students on the academic side of the campus. More recent explorations include extending VCL services to the administrative sides of several campuses. Not surprisingly, the biggest challenges to its deployment were not technological, but rather cultural and political. For example, many resource owners were not ready to give up ownership of their servers or were worried about server availability and quality of service. Job insecurity created opposition to widespread deployment in some departments and colleges that had their own IT shops. However, intensive education, thorough testing of VCL services before deployment, guaranteeing positive first impressions, and executive policy helped to overcome these social and political challenges. Ensuring that initial users had a positive experience created champions within a given department or college, which helped to accelerate adoption.

This same incremental process, assisted by the creation of campus champions, allowed for the more rapid expansion of VCL to many state universities and NC community colleges. Smaller state universities and community colleges "subscribed" for services by providing additional servers to the state education cloud, based on their anticipated usage patterns and needs. Because it collects the necessary statistics from its daily operations, the NC VCL can meter, and if need

be, charge for usage—an option that other state education clouds could choose to implement. Some campuses, like East Carolina University and University of North Carolina at Chapel Hill, have established their own VCL clouds. The resources of these clouds can be readily linked to the larger NC education cloud maintained by NC State, with additional hosting at the remote MCNC facility (formerly known as the Microelectronics Center of North Carolina), an independent not-for-profit institution supporting NC educational networking and other IT needs. Some private NC universities (such as Duke University) also have their own VCL installations. The existence of a successfully operating production cloud at NC State for many years—with its very real demonstration of enhanced services and reduced costs—convinced many CIOs, executives and key decision makers to adopt this cloud computing paradigm.

The NC Virtual Computing Lab Production/pilots/users also present within NC Community College System NC K-12

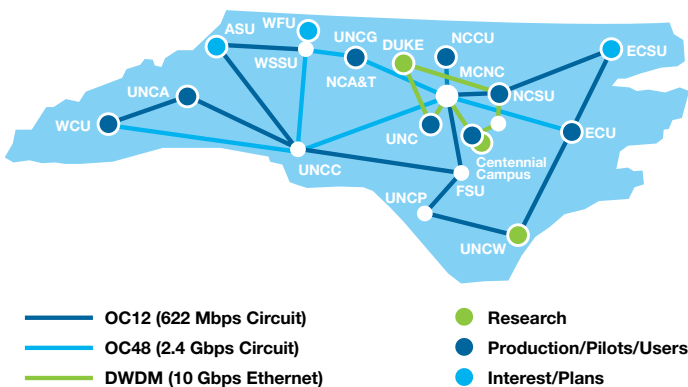|	
—— OC12 (622 Mbps Circuit)	● Research
—— OC48 (2.4 Gbps Circuit)	● Production/Pilots/Users
—— DWDM (10 Gbps Ethernet)	● Interest/Plans

Figure 1: The adoption of VCL across educational institutions in North Carolina.

NC State, through its Friday Institute and other K-12 outreach programs, as well as other universities, including North Carolina Central University (NCCU), Duke University, University of Maryland Baltimore County, Morgan State University, have been exploring the use of VCL in support of K-12 education. Duke faculty members are studying the use of VCL to deliver the Alice programming environment and Project Lead the Way software to K-12 educators and students as part of state-wide science, technology, engineering, and mathematics (STEM) programs. As part of an outreach project being led by faculty within the CIS Department at NCCU, instructors at Hillside New Technology High School in Durham, NC, are teaching with Alice software delivered by the NC VCL. A similar project for Baltimore inner-city students is being considered by School of Education and Urban Studies faculty at Morgan State University (again, using their VCL installation). In all cases, VCL is able to address the Child Information Protection Act (CIPA) requirements defined by the local school districts.

With a cloud paradigm, the technical support expertise must reside within the centers hosting the cloud computing resources. Since these centers can now be set up outside a K-12 school or school district, the local IT expertise required for the on-site IT infrastructure can be dramatically reduced, which is already the case in many instances. However, cloud computing still requires Internet connectivity and browser technology at the user site, so investment in statewide education network connectivity is strategic. The often-cited deployment model for VCL in the K-12 classroom is one in which a teacher provides thin clients that enable students to access the Internet and obtain advanced educational software and other resources and services, independent of the economic situation, technical infrastructure, or geographical location of the school district.

The current NC VCL servers are spread across a number of data centers several miles apart. The cloud paradigm allows servers and other resources from disparate locations to be managed as a seamless common pool that can be accessed by all. A state education cloud can therefore comprise resources from data centers located at several places across the state, providing, among other things, disaster recovery and contingency support, as well as addressing political and connectivity realities. It allows universities, community colleges and school districts with existing large data center facilities to provide at least partial support of such a cloud. In a recent proof-of-concept demonstrated to the NC governor, servers running VCL in the IBM Innovation Center in Research Triangle Park, NC were seamlessly added to the larger North Carolina State University education cloud — with users unaware that they were running on servers in an IBM data center. This provides the option for part or all of a state education cloud being hosted in a third-party data center — an important option if state-owned facilities are exhausted as more and more educational institutions join the cloud.

The bigger challenges are policies, politics and culture, with a strong need for "teach-the-teacher," as well as student, education programs. To date, university outreach programs, with their existing ties to the K-12 community, have been extremely important in the examples cited above.

Total cost of ownership savings

An initial study of TCO was performed by Wake Community College, a member of the NC Community College System that has 60,000 total full-time and continuing education students. The study determined that the annual TCO was reduced by nearly 50 percent when the college moved from a traditional IT infrastructure to a VCL-based cloud. Their annual IT costs before the transition were $1.04 million annually; after the switch, those costs dropped to about

$570,000 annually. Subsequent analyses performed by George Mason University (GMU), NC State and others, have shown even more dramatic cost savings — as high as 80 percent or more. For GMU, tremendous savings were obtained through the high degree of virtualization inherent in their Virginia VCL. Georgia State University also did a detailed analysis of student tech fee funding about $4 million per year over 10 years,[5] that likewise validated the cost and return on investment benefits of adopting a VCL-based cloud computing model.

Some of the sources of such significant cost savings have been discussed. These include maximized server and software license utilizations yielding decreased support and purchase costs, as well as virtualization. It should be noted that currently production VCL supports the popular VMware hypervisors. However, open source (free) hypervisor provisioning modules, for example, for KVM, are available for those who wish to use them. VCL supports a wide range of computing hardware platforms. Currently, NC State uses the free provisioning engine eXtreme Cluster Administration Toolkit (xCAT), with its list of supported operating systems and hardware platforms (http://xcat.sourceforge.net/). However, other provisioning systems, including IBM Systems Director® tools and IBM Tivoli® Provisioning Manager for Images technology, have been evaluated and can be implemented in a production setting.

Cloud computing is presenting both challenges and opportunities for software vendors, especially concerning licensing issues and cost models, causing some to embrace the changes, while others fear them. Clearly, given a large number of state education or other users supported by a single cloud, tremendous opportunities for license sharing across the state present themselves. State governments have the potential to negotiate large-scale software license purchases once, and not institution-by-institution or school district-by-school district, with implied bulk discounts. These opportunities are not unlike what many state systems have negotiated in the past for licenses for their student or administrative enterprise resource planning (ERP) systems. Likewise, because VCL collects all license usage statistics, metering of usage is possible and purchases can be based on the actual number of simultaneously used licenses across a given group, as opposed to estimates.

It should be noted that NC State currently requires approximately two full-time equivalents (FTEs), equal to one employee working 40 hours per week, to support the over 2,000 servers, 800 software images, associated storage and networks comprising its VCL. Some recommended configurations used at NC State are given in Figures 2 and 3. Note that in selecting servers for deployment in a cloud, the true TCO (power consumption, cooling, required support and other needs) over the life of the server should be of primary consideration, as such costs represent the predominant expenses associated with that server operating over its lifetime in a data center. The initial purchase price is typically a fraction of that total cost, and cheap servers are usually no true bargain.

Scaling VCL

Figure 3: A recommended approach for scaling up (i.e., adding more chasses to) an existing VCL set-up.

**Small VCL Configuration
Three Networks
Public, Private, Management, Intelligent Images, Security**

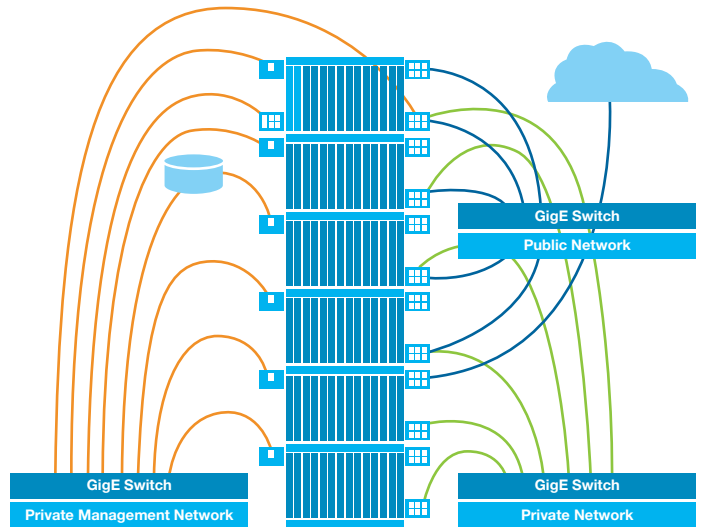*Figure 2:* A small single chassis configuration recommended for VCL.

Finally, several universities that are deploying a cloud anticipate some interesting benefits associated with traditional labs and/or student workstation spaces. Some look forward to the increased personal safety of their students (and the associated reduced security costs) due to the ability to close those labs at night—or even permanently. Students can access VCL using their laptops or workstations from their dorms or from home. Some universities are redefining those spaces for student collaboration environments or for other purposes and activities, saving construction costs.

Some of the benefits of VCL are summarized in the table below.

Beneficiaries	Benefits
Students	• Raises computing resource accessibility, even in underserved districts • Increases availability and integrity of data, applications and research materials • Adds mobility • Reduces client application and system resource footprint • Amplifies application and computing performance • Improves server and data storage capacity • Offers convenient web access to the VCL
Faculty	• Grants accessibility to virtual machines • Schedules delivery of assignment instructions, study materials, syllabi or software • Enables faculty to create custom images for specific course, independent of (and not conflicting with) other faculty course images • Unites departments and campuses to eliminate information silos to deliver comprehensive educations
Administration	• Standardizes applications and processes • Provisions software, resources and management of data • Lightens the burden of software version control • Reduces total cost of ownership by nearly 50-90 percent • Lowers the need for in-house IT staff • Cuts resource management costs including power and cooling • Raises server utilization and software licenses, reducing purchasing requirements • Brings greater virtualization • Optimizes resource allocation

Table 1 : Benefits provided by the VCL

The larger world-wide VCL community, including the Apache VCL project

Last year, with the assistance of the IBM WebSphere® Technology Institute, NC State donated the VCL code to the Apache Foundation, making it freely available to all and launching an associated open source software development community project (see http://incubator.apache.org/projects/vcl.html). As mentioned earlier, VCL has spread quickly to academic institutions in numerous US states, with pilots or production systems either planned or underway in North Carolina, South Carolina, Georgia, Virginia, Maryland, the District of Columbia, Tennessee, Louisiana, Arkansas, Kansas, Texas, New York, Pennsylvania, Ohio, Massachusetts, Rhode Island, Florida, California and Montana, plus Puerto Rico and other locations, with large-scale university system education clouds growing in North Carolina, Virginia and California. Others are being planned for states such as Tennessee and Maryland. Likewise, VCL is spreading abroad to countries and regions such as Canada, Mexico, Central America, Brazil, India, China, Japan, Portugal, France, Turkey, Eastern Europe and the Middle East; VCL is being explored even by universities in sub-Saharan Africa.

The most intense VCL collaborative activity has been among the universities along the US southeast coast, from Georgia through Maryland. Schools from Georgia, South Carolina, North Carolina, Virginia and Maryland, together with the 13 HBCUs comprising the Technology Transfer Project (TTP), have been meeting regularly as a group informally called the Southern State Education Cloud Consortium (see Figure 4). The objective of these meetings has been to share best practices, other information and documentation, plan and construct joint image repositories and other assets, work together on Apache VCL coding improvements, and plan and submit joint funding proposals to NSF, DoD and others. One project underway is the creation of a regional center of excellence in cloud computing.

In addition to supporting students and faculty at NC State University, the NC VCL now also supports students at other UNC System universities and NC Community Colleges. These include, among others, East Carolina University, North Carolina Central University, UNC Greensboro, NC A&T State University, Western Carolina University, Wake Technical Community College, Johnston Community College and Edgecombe Community College. The NC VCL also supports several K-12 pilots, including the NCCU-sponsored STEM outreach project with Durham's Hillside New Technology High School.

Similar VCL-based education clouds have appeared in other states. George Mason University has led the effort to establish the Virginia VCL (VA VCL), which includes Virginia Polytechnic Institute and State University (Virginia Tech) and others. In Georgia, the VCL effort is being led by Georgia State University, while in Maryland, the effort is headed by University of Maryland Baltimore County and Montgomery College. The California State University System, the largest university system in the US, has likewise begun to build a VCL-based education cloud. And within the Historically Black Colleges and Universities (HBCU) community, the HBCU Cloud initiative is being led by the TTP that includes, among others, Southern University (LA), Morgan State University (MD), Norfolk State University (VA) and Tennessee State University.

Most of the lead institutions for each state in the consortium, together with the TTP, were inducted as founding members into the IBM Cloud Academy (ICA). This larger consortium of educational institutions from all across the world has banded together to collaborate about cloud computing, promoting its adoption, extending the technology and infrastructure, creating shared repositories and assets, participating in joint research projects, and more. Several other member institutions of the IBM Cloud Academy are adopting VCL for their cloud infrastructure.
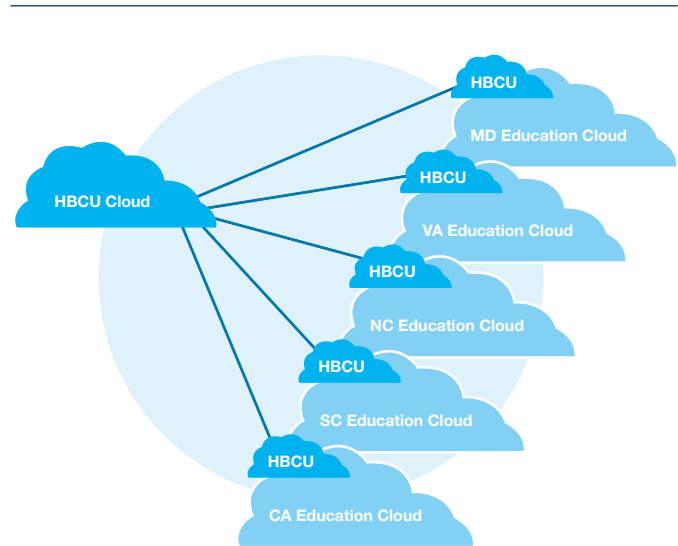

Figure 4: The Southern State Education Cloud Consortium, a cloud computing partnership among state universities in Maryland through Georgia that will also assist in supporting the HBCU Cloud.

An exciting cloud computing experiment is unfolding in Tennessee. Tennessee State University (TSU) has been working on a plan to support a VCL-based cloud pilot. And because it also provides IT support for both the McKissack Middle School in Nashville, Tennessee and Columbia State Community College in Columbia, Tennessee. It is hoped that the pilot project will provide an immediate, direct proof-of-concept (POC) for how those same improvements provided by cloud computing can be passed on to K-12 school districts and community colleges throughout the state. In parallel, the Tennessee Board of Regents (TBR), which comprises six state universities, 13 community colleges and 26 technology

centers, has been studying VCL as a solution to significantly improve the quality and access of education throughout the state. The expectations are that there will be simultaneous and dramatic reductions in current annual IT supports costs. Tennessee has the opportunity to establish the next state-wide education cloud in the US southeast, supporting its K-12 and higher education communities. By taking advantage of the lessons learned by the North Carolina education community, Tennessee can follow their neighbor's successful roll-out model—and move at a much accelerated pace.

State education plus and hybrid clouds

As efforts by the UNC System to support the administrative sides of its universities demonstrate, a VCL-based cloud can readily deliver applications and services supporting typical ERP systems, from student billing and payroll to class scheduling and grading. The CIO of Georgia State University has similarly embarked on a significant consolidation and virtualization of administrative computing as well as building interest in a state cloud to address current budgetary challenges. Work is also underway in North Carolina on medical and public health projects where the VCL will provide immediate, flexible applications and resources to respond to day-to-day needs and emergencies. Likewise, several cloud-based projects involving university outreach to the business community are suggesting ways in which VCL services can become an engine for economic development, beyond being a resource that supports continuing education and retraining.

As described previously, IBM and NC State University demonstrated how servers at their respective facilities could be readily combined to create a single private cloud—one in which the resources are dedicated to a single group or groups of users as, for example, all NC education. A few vendors, such as IBM, have also established public clouds, with services available on-demand to any user with a valid account. This includes the IBM Development and Test Cloud that is physically housed at the IBM Innovation Center in Research Triangle Park, NC, where some of the servers in the private cloud demo were hosted. IBM is currently testing a prototype plug-in for the Apache VCL code that allows users within a VCL-based private cloud to seamlessly request resources from the public IBM Development and Test Cloud. It will allow such private clouds to borrow resources from a public cloud on-demand and as needed, in response to dynamically increasing capacity demands, needs for specialized resources or applications, system failures or other emergencies. This capability is being developed in response to requests from several education and government clients. Figure 5 outlines the vision of such a hybrid cloud supporting the needs of NC education, and potentially more, including other government organizations.

There is a natural progression for state education clouds to expand in support of other state agencies, with the possibility of a single private cloud then simultaneously supporting all administrative, health, educational and research applications and services for a state. The privacy and security needs of different user groups can be addressed through user policy and resource partitioning. The ability to borrow resources from larger corporate-hosted public clouds provides greater security and stability than a private cloud as it grows. And with such a statewide government and education cloud, tremendous economies of scale be realized. Some of the recent developments in several states from VCL-based clouds could offer the opportunity to directly measure the incredible savings from the economies of scale provided by such large user populations.

The opportunity for a seamless integration of resources from the state and IBM Leadership Data Center facilities through cloud computing. Cost-effective, secure and "green" statewide on-demand delivery and sharing of educational content, state-of-the-art information technology resources and support.
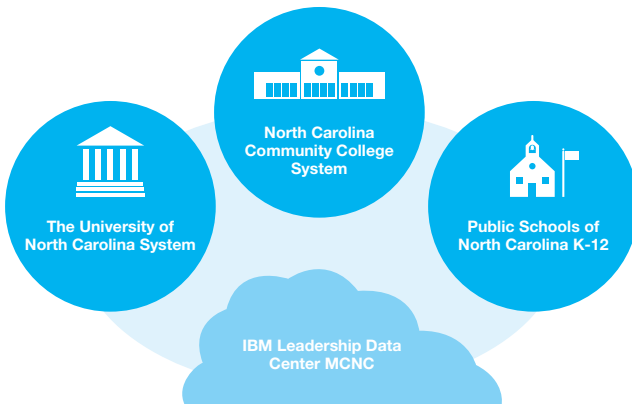

Figure 5: The proposed NC Education Cloud that would support all North Carolina educational institutions in the state, with servers housed on NC State University facilities, as well as MCNC (Microelectronics Center), a not-for-profit state organization.

Conclusion

The Virtual Computing Lab (VCL) is a technological paradigm shift that can dramatically improve the quality of education delivery for all students. VCL delivers advanced software and educational material, hardware, computing and storage resources, and services without the need for advanced in-house IT expertise. VCL delivers many significant benefits to students, faculty and administration, enabling new means of communication and collaboration for the users that form the heart of an academic culture.

VCL technology has been tested with visibly measureable results. VCL decreased the total cost of ownership, raised ROI and dramatically improved computing efficiency and performance at North Carolina State University. And because other universities have already led the way in implementing VCL, others can benefit from the reduced risk, best practices and lessons learned from these large scale roll-outs. The successful results gained from these relatively smooth campus transitions to VCL can be replicated by new institutions.

Recognizing the VCL developers and leaders

The VCL cloud computing solution was first developed by State University. The key team members there include: Sam Averitt, Andy Kurth, Aaron Peeler, Henry Schaffer, Eric Sills, Sarah Stein, Josh Thompson and Mladen Vouk. The Virginia VCL is led by Sharon Pitt at George Mason University. The Georgia State University VCL team includes JL Albert, Yi Pan, Art Vandenberg, Kelly Robinson, Davide Gaetano, Stephen Ford, and Naixue "Neal" Xiong. The University System of Maryland pilot is being supported by Jack Seuss (University of Maryland Baltimore County) and Michael Russell (Montgomery College). In Tennessee, Dennis Gendron (Tennessee State University) and Tom Danford (Tennessee Board of Regents) have been the primary drivers. The HBCU Cloud effort is being led by Ramon Harris (Technology Transfer Project).

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