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Platform Architecture and Features for Thin-Client/Server Delivery for Oracle Interface and Tools

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PLATFORM ARCHITECTURE AND FEATURES FOR THIN-CLIENT/SERVER DELIVERY FOR ORACLE INTERFACE AND TOOLS

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Abstract

As the popularity of eLearning continues to grow, more and more academic institutions and corporate training and development departments are developing content and delivery systems for Internet based "online" education, training and development. Oracle lab environments may call for access to specific Oracle applications, products, and tools, and the feasibility of having every user or student locally install a required lab environment is low due to constraints with licensing, technical support, local hardware and software available, and the level of expertise of the end-user. The use of thin-client technology appears to present a solution to this problem. This report reviews the design and implementation of an extensible eLearning Information Systems architecture that allows integration of Oracle 8i and 9i development and administration tools with content delivery systems in online corporate training and development initiatives, and distance education and eLearning programs by delivering a "virtual-lab" (V-lab) environment. By utilizing current compression and streaming technology from protocol vendors such as Citrix, the advent of the "thin-client/ server laboratory", or V-lab, is here and is supported by an educational format (pedagogy) and information systems architecture that significantly advances the ability of corporate and educational institutions to deliver viable, quality instruction of Oracle application development tools, GUI based resources, and Information System modeling and data analysis tools via the web. Attendees of this presentation will be familiarized with the platform architecture and associated technologies used to integrate and deliver GUI application based tools with the academic course content through the Internet, as well as the concept of "infomediation". The principle outcomes of the report will be a detailed analysis of the platform architecture and associated Internet, broadband, and application integration technologies used to deliver Oracle via thin-client/server technologies, the performance metrics of the platform, a suggested academic support model, and associated deliverables for designing and implementing the system with new and existing organizational information systems.

Keywords: Thin-client, virtual lab, v-lab, e-learning, platform, architecture, Oracle, SCORM

Introduction

To compete in an era of digital competition, education institutions and corporate training initiatives are faced with the continuing challenge of building efficient and effective eLearning networks. The integration of corporate training and higher education programs of instruction began in the industrial age with the corporate sponsorship of higher education institutions by such notable universities as Johns Hopkins and Cornell (Gold, 1981). Since that time, the significance and importance of the relationship between higher education and training and development has increased through the advent of the industrial age, technology age, information age, and now the knowledge age. These mega-trends have seen the convergence of higher education and training and development purpose (Naisbitt and Aburdene, 1991). Corporate Human Resource Development (HRD) training and development initiatives are concerned with efficient and effective training, and academia is concerned with sufficient applied learning in their curricula (Hanna, 2000). In effect, the eLearning network, for both higher education and corporate training and development, requires solid instructional system design (ISD), content mobility, and a scalable infrastructure that can maintain synchronization between the content development and learning or course management systems, and the technology required for delivery. In other words, the content or learning objects development must develop and implement in-sync with the technology migration of the delivery platform. The highest form of evolution in the convergence of the content or learning objects development and the technology platform is "infomediation", where the organization is able to essentially broker content, assimilate learning objects based on prescriptive diagnostics and needs assessment, provide an integrated eLearning environment for cognitive, affective, and psychomotor ISD objectives, interactively connect to external knowledge bases, and implement work-flow concepts related to student services and management. Current course management systems, such as WebCT, eCollege, and BlackBoard, are effective, web-base applications that allow for basic functionalities like course administration, grade book, email, chat, document sharing, digital drop boxes, journaling, and webliography. This accommodates the cognitive objectives in the typical ISD framework, and can accommodate the affective objectives, but the psychomotor and skill based objectives are not facilitated. A virtual laboratory environment, or a means to deliver the practical applications, skill training, or reinforced learning obtained through hands-on experiential learning requires a distinct environment. Using the Internet as the platform for global delivery is a requirement not only for the course content, but for the experiential learning as well. Some solutions have been to provide remote application server (RAS) connections into these environments, or use network services such as Telnet to connect to laboratory applications over the Internet. But these solutions are minimal at best, because they are generally limited by security restrictions, bandwidth issues, or command-line only environments, thus excluding training environments for graphical user interface (GUI) applications. So the question is, given the need to deliver all forms of application environments via a predominantly IP network, how do you implement a globalized, independent computing architecture that is not encumbered by disparate operating systems, network protocols, or bandwidth limitations? The answer begins with a review of the development of the principal platform for delivery: the Internet.

Internet Development

TCP/IP refers generally to a communication protocol that is derived from two separate protocols (Clark, 1999). Transmission Control Protocol (TCP) is a connection-oriented technology and provides for reliable transport of data packets on top of Internet Protocol (IP). IP is a connectionless and basically unreliable data packet delivery technology. Network attacks are generally against TCP/IP networks, so it is important to understand the fundamentals of TCP/IP and how it became the protocol standard for the Internet. Starting in the early 1960s, the Defense Advanced Research Projects Agency (DARPA), an organization of the United States Department of Defense (DoD), were asked to do some research and development with the goal of designing a communications matrix that would be sustainable even with catastrophic node and circuit disruption. Packet switching seemed to be an obvious solution, so as a result, DARPA started to sponsor organizations and select research laboratories in interconnecting hosts that used packet switching technology. The initial network protocol was a host-to-host protocol known as the Network Control Protocol (NCP). The result was the predecessor to the Internet, known as ARPANET. By 1969, ARPANET interconnected four hosts located at university research facilities. These universities were the University of California at Los Angeles (UCLA), the Stanford Research Institute (SRI), the University of California at Santa Barbara (UCSB), and the University of Utah (Oppliger, 2002). ARPANET was introduced to the general public in 1972, and in 1980 the DoD recommended TCP/IP, with a full implementation of TCP/IP in 1983. At that time, the network was split in MILNET, which supported military operations, and ARPANET, which supported academic and research needs. By 1985, the Internet was growing in acceptance into the private and business communities, and the proliferation of applications other than email was starting to accelerate. The term "Internet" was officially adopted and defined by the United States Federal Networking Council (FNC) in 1995. The FNC also formally defined the Internet in a FNC Resolution at that time. In the definition, the Internet is defined as a global information system that is able to support communications using the TCP/IP protocol suite or its subsequent extensions or follow-ons (Council, 1995). So the standardization of the TCP/IP protocol suite was a good thing in terms of worldwide connectivity and the evolution of the World Wide Web, but a bad thing because now the entire network was subject to an easier attack strategy. To promote standards and governance on the Internet, the Internet Society (ISOC) was formed with current participation from over 11,000 members in 182 countries (ISOC, 2002). A technical body of the ISOC is the Internet Architecture Board (IAB). The IAB has two task forces, one of which is the Internet Engineering Task Force (IETF).

The next generation Internet is known as Internet2. This new initiative has several sponsors, an important one being Tim Berners-Lee and the World Wide Web Consortium (W3C). Internet2 is driven by a consortium of corporate leaders and education institutions with the charter to create the next generation Internet, characterized by higher bandwidth, managed bandwidth through quality of service (QoS), and introduction of the IPv6 protocol. The nationwide backbone network for the Internet2, known as the Abilene Network, is specifically designed for transport of multimedia objects associated with education, training, and development initiatives. As learning objects are created in the advancement of eLearning ISD systems, SCORM (Shareable Content Object Reference Model) compliant and AICC (Aviation Industry CBT Committee) compliant repositories, they will contain indexed links to multimedia datatypes that will need to port across the network. Ideal candidates for utilization of Internet2 would include the Global Knowledge™ initiative to bring integrated Blended Learning services to enterprises around the world using Oracle iLearning as the Learning Management System (Barlas, 2002).

Thin Client vs. Fat Client

A "thin" client is defined as a low-cost, centrally managed computer devoid of CD-ROM players, diskette drives, and expansion slots. The term derives from the fact that small computers in networks tend to be clients and not servers. Since the idea is to limit the capabilities of these computers to only essential applications, they tend to be purchased and remain "thin" in terms of the client applications they include. The term "thin client" seems to be used as a synonym for both the NetPC and the network computer (NC), which are somewhat different concepts. The Net PC is based on Intel microprocessors and Windows software (Intel was a leader in defining the Net PC specification). The network computer (NC) is a concept backed by Oracle and Sun Microsystems that may or may not use Intel microprocessors and uses a Java-based operating system. According to ThinPlanet.com, a Web site dedicated to thin client technology, the term "server-based computing" is being used as a synonym for "thin client" because most thin clients today are powered by back-end centralized servers that are capable of serving either fat or thin clients (WhatIs.com, 2003). Of course, the browser could also be considered a form of thin client, and for the purposes of this report a thin client should be viewed more in that context than a hardware context. And by contrast, a "fat client" is just the opposite of the thin client, and tends to have relatively strong processing capabilities.

A new paradigm, promulgated by the Citrix Corporation, is the concept of a "Thin-Client/Server" technology. So how is this different from just "thin client" technology? The answer is that rather than adhering to a strict client-server platform concept and using the server for all processing, and running the application on the thin client, the application is also run on the server side and only an image (pixel emulation) is delivered to the thin client. Everything is implemented at the system level so that conservation of bandwidth is preserved through all processing, both application and interface, occurring on the server side. No calls are routed to the application through the client side, but rather only a representation of the interface. Applications execute 100% on the server side of the network.

The Regis University Academic Research Network

The Academic Research Network (ARN) began development in 2000 to service the needs of students in the University's MSCIT Program. The network is currently in a state of maturing development, and has passed almost two years of testing and is currently supporting 100% of the Oracle Database Technologies student labs. The ARN is capable of delivering applications via the Internet using Citrix "thin-client/server" technology. With access to the Internet, students around the world can use their v4 or higher browser to connect to the ARN and the lab applications that support their coursework. The goal of the ARN is to create a research and academic support network with global connectivity that could be jointly managed by Regis University MSCIT students studying in the Database Technologies and Network Engineering Technologies emphasis areas. The entire ARN infrastructure, including the network backbone, the web servers, the Oracle database servers, the Oracle Internet Application Servers, the application servers, and the storage tier devices are managed under the supervision of the MSCIT Lead Faculty in each of the respective areas.

Why a Thin-Client/Server Architecture?

Although the Internet provides a ubiquitous delivery platform, there are other issues with delivery of a "lab" environment since users do not work from a standardized operating system, system resource, level of expertise, or bandwidth. Also, the eLearning model indicates progression to mobile learning, or mLearning, which would call for the ability to deploy learning objects, and the lab environment, to an 802.11 compliant network (Bielawski and Metcalf, 2002). Thin-client/server technology affords the best technology solution and lowest total cost of ownership for delivering the lab applications to a heterogeneous user group. Regardless of the client operating system, a customized Windows 2000 or XP desktop can be delivered to the user via the Internet.

How Does Citrix Work?

The Independent Computing Architecture (ICA™) technology levels the playing field for the deployment of Microsoft Windows and other 32-bit user-mode operating system applications. It is independent because it does not matter what location, hardware, operating system, or bandwidth is available on the client. ICA technology involves three components: a server software component, a network protocol component, and a client software component. The ICA technology can uniquely separate the application logic from the user interface. The network component is responsible for transporting keystrokes, screen refreshes, and mouse clicks. The average bandwidth consumption to do this is approximately 20kbps on the network (Citrix, 2003). Users only see and work with the interface for the application. ICA is highly efficient because everything is implemented at the system level. By comparison to network bandwidth consumption via dial-up, LAN or WAN connections, delivery of the application interface via ICA technology can be as little as one-tenth of the other technologies. Server based execution of the application combined with low bandwidth consumption allows for acceptable performance of even robust 32-bit applications across legacy operating systems on modem speeds.

Some of the key differentiators in the ICA technology include the ability to operate on very thin CPU and primary memory resource devices. This takes in the full range of Personal Digital Assistants (PDAs), and iPAQ-like devices. Since managed bandwidth is critical, the ICA stream consumes an average of 20kbps of bandwidth, by contrast to download and run objects. ICA is platform and protocol independent to include non-DOS devices and the full range of industry standard protocols, including TCP/IP, NetBEUI, NetBIOS, and IPX/SPX; as well as industry standard communications including ISDN, B-ISDN, Frame Relay, ATM, and 10 Gigabit Ethernet (Citrix, 2003).

The Interface

Using Citrix proprietary technology, the ICA client, allows students worldwide to connect to the appropriate applications for their course of study. ICA stands for "Independent Computing Architecture" and is the enabling technology and premiere product implementation of the Citrix Corporation, headquartered in Ft. Lauderdale, Florida. The ARN utilizes the Citrix server client application, known as NFuse, to "serve up" software applications on the Internet. The Citrix server, architecturally, is placed between the user on the web and the server running the course software application. The first step in the process for the student is to download the Citrix ICA "client" on to their local personal computer. This is an easy process that anyone familiar with downloading from the Internet can accomplish in a few easy steps. Students are supplied with a Uniform Resource Locator (URL) to go to the Citrix Metaframe server on the ARN.

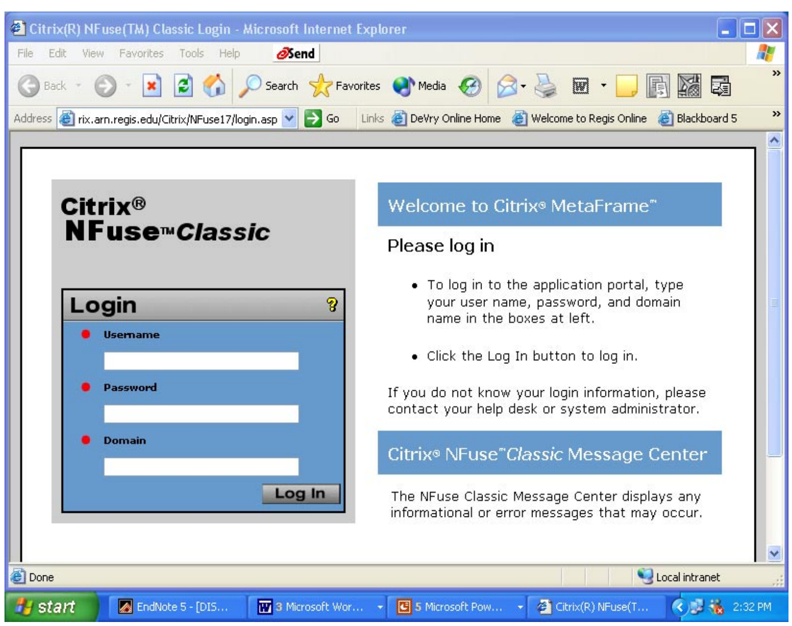

Figure 1. Virtual Lab Portal Interface

Downloading the Citrix client software takes less than 1 minute on a 56K modem, or about 15 seconds on an average broadband connection. The Citrix ICA client has a very small footprint (less than 200kb). The file is downloaded as a self-extracting executable and can then be installed into the local computer's program file directory. The student user then closes their web browser, and opens it again to find the Citrix NFuse logon screen at the previously supplied URL. This screen (Figure 1) is the "gateway" interface to the student's particular course software application.

The next step in the access process is to logon to the Citrix Metaframe server by supplying username and password (credentials) to access the course software applications. The Citrix Metaframe server is an intelligent system and recognizes the user by his/her profile. The user profile information tells Citrix which applications the user needs to access, so custom "desktops" can be created to serve users and students in various disciplines or departments. After logging on, the user/student will see a desktop similar to the following (Figure 2).

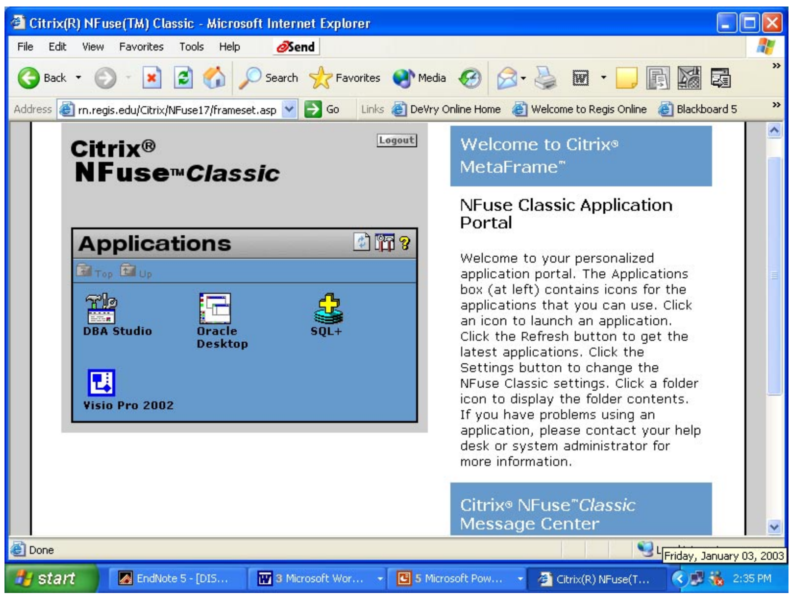

Figure 2. Portal Applications After Login

So based on what course(s) a student is taking in the current term, they will see icons for the software applications that they need to complete their course lab work. Custom desktops can be created so that it is possible to deliver a Windows 2000 or XP desktop to a remote client with a Linux, Mac, or Win9x operating system.

The ARN Architecture

The ARN is designed and developed on an N-Tier platform architecture that separates storage, DBMS instance, applications, and web interface tiers for horizontal scalability and ease of administration. The backbone provides broadband connectivity to the Internet from the campus locations so that a form of Virtual Private Network (VPN) is implemented, allowing distribution of the server farm over three primary locations: the Lowell campus, the Southeast campus, and the Broomfield campus. The purpose of distributing servers at separate geographic locations on the network concerns manageability, space utilization, and infrastructure resources. The architecture has horizontal scalability, meaning that as demand for network resources grows, the ability to service increasing numbers of students is as simple as adding additional servers to the appropriate tier and purchasing more Citrix licenses for thin client access. The following illustration (Figure 3) shows the basic configuration of the inbound network via the Citrix Metaframe servers to the Oracle instances.

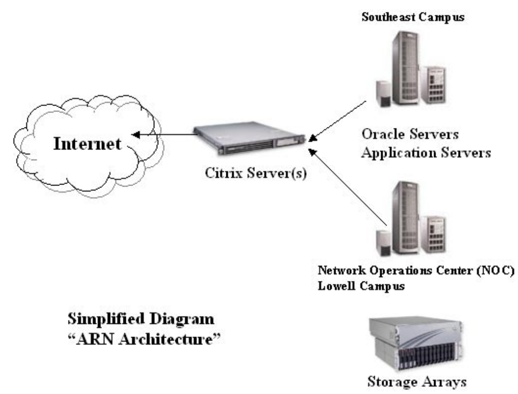

Figure 3. Simplified Diagram of the Academic Research Network

Configuration of Citrix to the Oracle DBMS Instance

There are several technical notes in both the Oracle and Citrix knowledge bases that indicate design is unsuccessful when the Oracle server and applications are installed directly on the Metaframe server. Connectivity errors occur as a result of this configuration. The configuration used in the ARN is to have two Citrix Metaframe servers on the front end of the access network to provide for load balancing and fail-over capability. The Metaframe servers operate at the (web) application tier, in effect as a middleware solution. The Oracle DBMS servers operate at the database tier behind the application tier, and are configured either as a single instance with multiple user accounts for more "static" classes, or as multiple instances with single users for "dynamic" classes where student users need access to their own instance. The Oracle client and application tools are installed on the Citrix Metaframe servers, with TNS connectivity to the respective instances operating at the database tier. Physical database files reside at the storage tier on network attached storage.

Oracle User Account Administration - Citrix and LDAP

Citrix user accounts are separate from Oracle user accounts. The Citrix Metaframe server inherits user metadata via a LDAP connection to a network operating system using a directory (like Novell Directory Services or Microsoft's Active Directory). In this case it is Microsoft Server 2000 Active Directory that provides the account information to the Metaframe server. Oracle user accounts are administered directly through the Oracle DBMS, so at present state there is no single sign-on (SSO) in the sense of seamless connectivity between the two environments. This is a next stage of evolution that will be accomplished through application integration via a portal mechanism. There is SSO in the sense that usernames and passwords are consistent between the two environments.

The following illustration (Figure 4) shows how all locations can access the ARN using a browser with a connection to the Internet.

"Thin-Client/Server" Global Access to Oracle

Access to the ARN and its resources is global using the Internet. Using either Netscape or Internet Explorer (preferred), users can access the ARN from any location in the world. Users can be local classroom based or eLearning students, faculty members, and the administrative support members in the hosting MSCIT Practicum. This allows the MSCIT Program to support Blended Learning and to provide software application support worldwide for the curriculum lab work in tandem with the content delivery, be it physically in the classroom or virtually via WebCT. By downloading a simple client interface (Citrix NFuse) to their local computer, there is worldwide access to any course custom lab environment. The following illustration (Figure 5) shows the architecture for global access to the ARN.

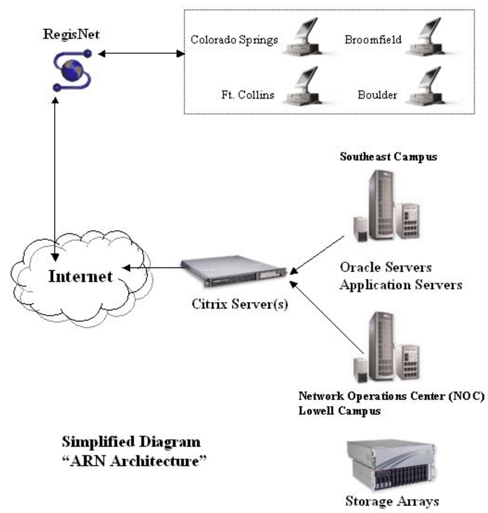

Figure 4. Internet Access to the Academic Research Network

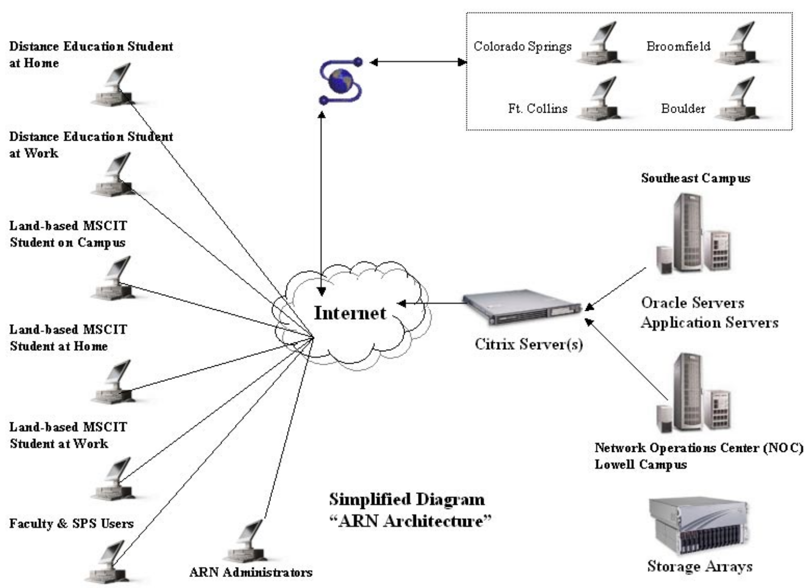

Figure 5. Global Access to the Academic Research Network

Cost-Benefit Analysis

One of the major contributing factors to student persistence (retention) in an applied science program is the level and quality of applied learning (hands-on) experience that students receive in the course of instruction. Frustration with lack of laboratory work, or problems with the platform or applications, can present a significant increase in the level of student dissatisfaction, and consequently yield high attrition rates. Looking at the attrition as a function of tuition revenues, even modest increases in student retention can result in a very acceptable return on investment. In the sample population studied for this report, the average tuition for a semester was $2,054.00. The average student population size over the twelve month period studied was 525 students. Prior to the implementation of the V-Lab platform, student attrition in the program averaged 18% over the twelve month period. After implementation of the V-Lab platform, student attrition in the program averaged 12%. The difference in persistence rates calculates to an increase in tuition revenue (found monies) of $194,103.00 over the twelve month period. The capital expenditure for the V-Lab platform, including software licenses and hardware, was $72,000.00. Over the depreciated life of the equipment (based on a five year depreciation schedule), the gross return on investment (ROI) with no other variables allowed is calculated at 646.93%.

Platform Extensibility to mLearning

The mLearning concept is a natural extension of the eLearning network platform, and provides for an even greater measure of content and user mobility. Just as in the Internet platform delivery of content via learning objects and lab environments through thin-client/server technologies, the mobile learning environment must accommodate the same. So what is happening with the IEEE standards for wireless, mobile applications that will allow for implementation on wireless networks to remote devices such as PDAs or mobile PCs? The desire for ubiquitous connections to data, resources, web applications and the Internet is a major factor in the evolution of the IEEE standards for wireless network technologies. Wireless devices are a natural extension of the local area network and allow the user to become mobile to various degrees. Gast (2002) indicates that wireless networks often extend an existing wired infrastructure. There is also significant interest in extending the connection to the enterprise network to situations that indicate no practical solution to network connectivity. Examples might be the trading floor of a stock market exchange, or the floor of a manufacturing facility. Wireless networks were not initially well accepted by business and industry (White, 2002). Most likely this was because of the lack of technology standards, lack of application of the technology, performance of the wireless network, and a lack of understanding in how to engineer wireless network solutions. When the IEEE approved the 802.11 standard for wireless networking in June of 1997, the acceptance, use and proliferation of wireless networking technology began to increase (Littman, 2002). A wireless network allows a user, via some hardware device, to access a network that is either internal to an organization, or a network that provides access to the Internet. Mobility of the user is predicated on the wireless technology standard used, as some standards provide for greater bandwidth and reach than others. Wireless local area networks (WLANs) do not follow any particular design or pattern, so the question of the wireless network topology is rather fluid. According to Gast (2002), each WLAN deployment is unique. There are three conventional architectures for WLANs. The basics include the user with some mobile device that connects via a wireless network interface card (NIC) to what is referred to as an access point. An access point is a control module that interfaces and connects the user device into the network. The user device, a laptop or Personal Digital Assistant (PDA) for example, transmits and receives at the specified IEEE 802.11 standard to the access point to achieve the wireless connection to a specified network. The wireless connection can be achieved generally from a few feet up to 800 feet between the device and the access point (Gast, 2002). The first of the conventional architectures is known as a Basic Service Set (BSS). The BSS configuration is one where the LAN has one “cell” with an access point in the middle of it. Typically, the access point is connected to the hard-wired LAN. The second architecture is referred to as an Extended Service Set (ESS). In this wireless LAN configuration there is more than one cell, all with associated access points, much like a cellular telephone network. The user can extend mobility by connecting from one cell to another. The third architecture is a peer-to-peer architecture where each device communicates directly with the other devices on the network. According to White (2002), this is referred to as an ad-hoc configuration for a wireless LAN. The IEEE 802.11 standard specifies and defines wireless local area network (WLAN) operations at the Physical and the Media Access Control (MAC) layers of the Open Systems Interconnect (OSI) model (Littman, 2002). According to White (2002), three different types of Physical layer connections are defined. These include infrared transmission, a direct sequence spread spectrum technology, and a spread spectrum technology that uses frequency hopping (known as Frequency-Hopping Spread Spectrum, or FHSS). Other sources, however, also include for the complete range of 802.11 standards a definition of laser technology, microwave technology, and satellite technology in the physical layer specifications. There are a wide variety of local area networks, and the IEEE 802 suite of protocol specifications was created to accommodate them. The IEEE 802.11 standards are specific to wireless network standards. Wireless networks allow for user mobility and the ability to “roam” within the confines of a LAN. This is different from “portability”, where users are able to connect to different networks at different locations. Mobility, according to Gast (2002), is actually a more powerful concept, in that it gives the user the capability of movement within a LAN environment. It removes barriers that are largely based on physical network architectures. Dataports to an Ethernet network provide for portability, whereas wireless connections provide for mobility. In order to accomplish this, and ESS architecture, or topology, allows for roaming by spanning multiple locations through the link layer. Network layer mobility is generally not available on an IP network, meaning that the access point for the wireless network needs to be connected to a single IP subnet (Gast, 2002).

Oracle iLearning and SCORM XML Compliance

Much like other public and private exchanges that specify the grammar for XML repositories, there is an evolving standard for the exchange of learning objects via XML. The Shareable Content Object Reference Model (SCORM) is becoming a standard for the exchange of academic, training, and development content across the web. It is built upon the work of the AICC, IMS, IEEE, ARIADNE and others to create one unified "reference model" of interrelated technical specifications and guidelines designed to meet the DoD high-level requirements for Web-based learning content. Knowledge repositories that are "SCORM Compliant" will be able to interact, connect, and otherwise exchange or sell knowledge between organizations and the DoD. Oracle's premiere Learning Management System, known as iLearning, is capable of hosting an XML compliant repository via the Oracle DBMS, and is a fully supported system for managing learning objects as well as student information and metrics. Oracle productized this technology that was initially developed for the Oracle University, and it is now part of the Oracle e-business suite. Oracle foresees growth in the eLearning marketplace (Barlas, 2002).

Future Directions….Towards Infomediation

The ability to deliver global access to required course software applications and lab environments via the Internet is a key differentiator between any academic or training and development organization and its competitors. As corporations, colleges and universities vie for the ability to deliver training in the Internet space, the advancement of the virtual lab concept is a key competitive advantage and a clear differentiation.

The Citrix technology can be integrated with the Oracle 9iAS portal product to create a single sign-on to two environments: a content rich portal, and any number of applications. Out of necessity, mobile wireless devices have inadequate RAM, processing capability, and communications bandwidth to handle Windows-based database applications and tools. Citrix technology can be used to resolve that issue and extend the eLearning lab environment to the wireless web user.

An "infomediary", as defined by Turban, King, et al. (2002), is an electronic intermediary that controls the flow of information. So infomediation is the provisioning and brokerage of knowledge and information, in this case by the academic or corporate training and development organization.

Future directions of this technology are to move the organization towards infomediation and look for new ways to use the power of the Internet to provide curriculum and instruction to students and employees by extending the architecture to the wireless, mobile platform, and utilizing the Oracle DBMS capability to host and manage XML to create a system where it is possible to connect into many different knowledge bases and learning object repositories for the purpose of providing more content and mobile content to academic and corporate users to service the education, training, and development needs of the business enterprise.

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